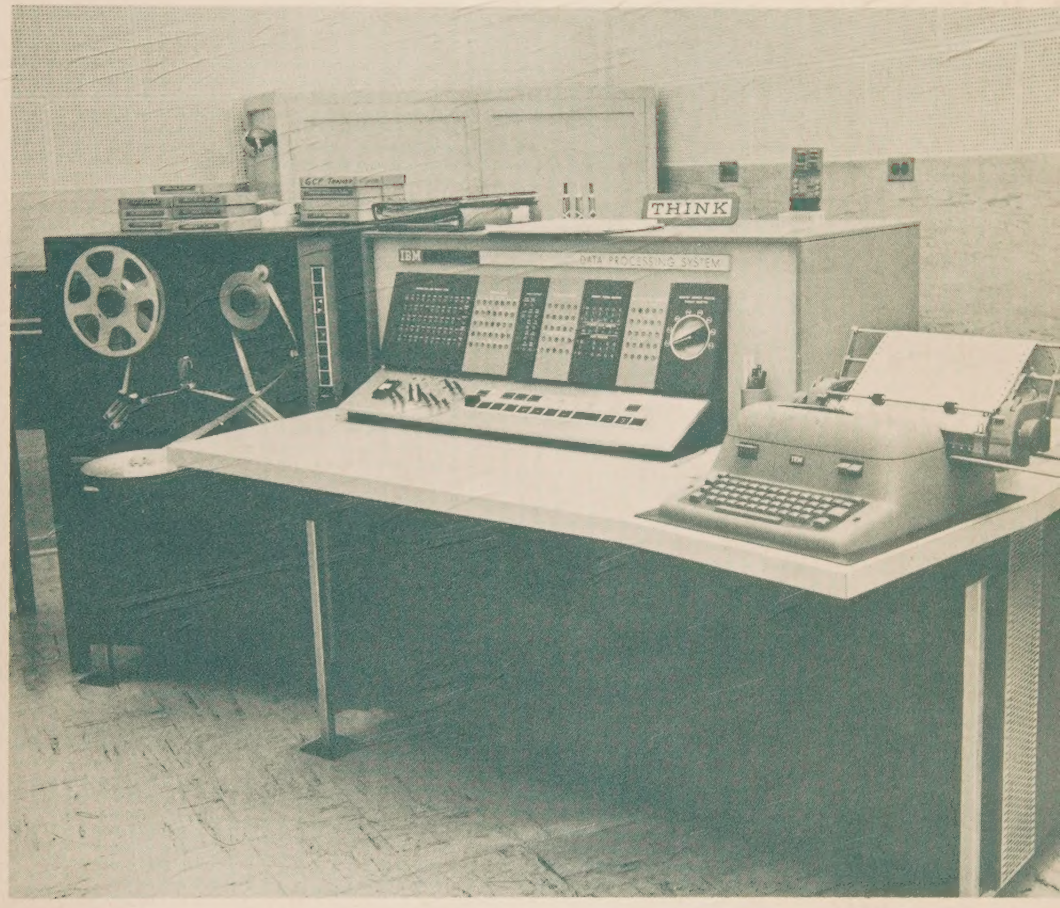
Experiment Station, Hawaiian Sugar Planters' Association



1961

ANNUAL REPORT

5 MAR 1962

Digitized by the Internet Archive
in 2025

https://archive.org/details/annual-report-hawaiian-sugar-planters_1961

Experiment Station, Hawaiian Sugar Planters' Association

REPORT

October 1, 1960 to September 30, 1961

---

letter from the director . . . . . *iii*
cultural practices *1*
diseases *17*
experimental statistics *24*
factory *25*
insect and rat control *28*
irrigation *32*
mechanization *46*
tillage *52*
varieties *54*
weed control *63*
personnel training *71*
experiment station staff *73*
station personnel changes *75*

On the cover:
IBM 1620 computer installed this year in the
Station's Experimental Statistics Department

FROM THE DIRECTOR

to the president and members
hawaiian sugar planters' association

Gentlemen:

I am very happy to present to you the Experiment Station Report for the year ending September 30, 1961. The contributions of a competent and dedicated staff reported herein serve as a reservoir of scientific facts so essential to solving the many technical problems facing the Hawaiian sugar industry. Although the contents of this report bring out clearly the results of the many facets of the research program, there are several important developments that warrant special emphasis.

The statistical analyses of Station research have been speeded up by the use of an IBM 1620 Computer. Certain of the research data that used to require many man-hours of work can now be processed in a few minutes. The gamma ray bagasse-weighing device has been installed in four locations, giving the first reliable continuous weighing of the amount of material passing through the mill.

Harvesting research resulted in preliminary field trials of a cut-convey-load harvester at both Laupahoehoe and HC&S. A self-transload cane buggy was part of the equipment at the Laupahoehoe trial. Preliminary studies on sugar losses have indicated that these harvesters have the potential of saving considerable sugar over present methods. Seed-cane harvesters have been functioning at both Kohala and HC&S; three other plantations are fabricating similar machines.

In the area of irrigation, research has shown that water consumption by the cane plant after the canopy has been established is approximately the same as the evaporation from a Weather Bureau evaporation pan. The 4-5 internodes of the cane stalk have proved to be sensitive to moisture stress and not affected by plant nutrients, thus providing a reliable tissue for measuring irrigation needs.

The root system of the cane plant has come under scrutiny from several different techniques of research. It was found that roots from new shoots grow at a rate of 1 to 3 inches per day. It has been definitely established that the plant roots do not contribute to the nutrition and water requirements of the subsequent ratoon.

Research on the early induction of flowers in 37-1933 through photoperiodism has resulted in making the first crosses with early-tasseling canes.

During the past year several significant developments took place with respect to the Station's research program in its relation with the plantations.
First, a series of seminars was inaugurated which carried Station research to the different sugar-producing islands.
Second, the publications of the Station were revised to bring research information immediately to the plantations in more readable format. All of these publications, including this Annual Report, were produced at the Station by Station personnel, resulting in better media of communication at lower cost.
Third, the Station research projects have all been revised and are being presented to the industry to show the objectives, the anticipated practical results, and the funds being used to carry out the research on each project.

Dr. L. G. Nickell, formerly Head of the Department of Phytochemistry, Chas. Pfizer & Co., joined the staff on June 26, 1961 as Principal Physiologist and Biochemist to replace Dr. G. O. Burr, whose retirement date is November 1, 1961.

The Station Library now contains 73,912 catalogued items. Nearly 3,000 items were circulated to the staff, trainees, and non-staff personnel during the year.

Respectfully submitted,

L D Baver

CULTURAL PRACTICES

varieties may differ in response to applied fertilizer

Failure to realize that varieties may differ in chemical composition under a given set of growing conditions has led to some uncertainties in the use of crop logging as a means of assessing the nutrient status of the cane crop. This viewpoint was emphasized in the 1960 Annual Report (pages 8-9) and is further confirmed by evidence obtained from Variety x Amounts-of-Fertilizer (VxAF) experiments carried out on Hawaii. Data from several VxAF experiments illustrate the following points:

1. The K content of 8-10 internodes may differ widely among varieties for a particular fertilizer treatment in certain experiments, but not in others. For example, striking differences between 49-5 and 44-3098 occurred in Experiment Puna 121a, but not in Puna 121c nor in Experiment 114, Hamakua Mill Company.
2. The N content may differ widely among varieties at certain locations while at others differences may be relatively small (e.g., Puna).
3. An overabundance of N at six to eight months of age is indicated in certain experiments, even at the minimum level of fertilization. The contrasting data for Hamakua Mill and Puna experiments probably reflect, in part, differences in residual N from the previous crop.
4. The minimum level of fertilization frequently was too high to establish a response curve; hence, it was not often possible to interpret yield response-crop log relationships.

The need for obtaining further information on varietal differences in response to fertilization, with reference both to crop yield and nutrient uptake, has prompted the installation of several new Variety x Nitrogen experiments on Hawaii, Kauai, and Oahu. In these studies, the objective is to define the complete nutrient response curves for varieties. This information, along with appropriate soil and plant composition data, should permit determination of:

1. Optimum level of N fertilization.
2. Amount of N (total uptake) associated with various yield levels.
3. Levels of 8-10 N associated with optimum yield.
4. Relation of residual soil N to crop response from N fertilization.

Similar experiments will be installed to study variety-potassium relations.

more about replanting

Earlier experiments (see page 5, 1959 Annual Report) raised serious doubts concerning the economy of replanting 3-, 4-, or 5-foot gaps. Results indicated poor survival and spindly development of replants. Four recent studies (three at Kahuku and one at Grove Farm) showed no increases in TCA or TPA due to replanting.

The comparisons in current experiments were made between plots in which 0, 25, 50, 75, and 100 per cent of the blanks were replanted, irrespective of the number or sizes of blanks existing in the plots selected. The method of random selection adopted provided insurance that different blank sizes would be sampled in accordance with their frequency of occurrence in the field. In the four experiments, 3- and 4-foot blanks were most prevalent, comprising 65, 71, 60, and 57 per cent of the replanted blanks (Table 1). The larger blanks (greater than 7 feet) occurred much less frequently, in keeping with the usual situation encountered in the field.

TABLE 1. *Proportion of replanted blanks of different sizes.*

LENGTH OF	% OF REPLANTED BLANKS WITH 3-4 FT.	5-7 FT.	<7 FT.
KAHUKU			
FLD. 7	65	22	13
FLD. 12	71	29	0
FLD. 43C	60	32	8
GROVE FARM			
FLD. K-17	57	33	10

In these experiments, appreciable amounts of cane and sugar were derived from replants, particularly with 100 per cent replant. At this level, for example, replant cane comprised 20 per cent or more of the cane tonnage. It appears obvious, therefore, that replant cane reduced yield of surrounding cane. Conversely, without replanting, cane surrounding the blanks developed more fully.

potassium moves from point of application

A brief laboratory study was made of the lateral movement of applied potassium in moist soil. This study followed the observation that under unirrigated conditions K may move away from the point of application in the cane line, even in the absence of crop uptake or appreciable rainfall.

A Puna soil, which had not been permitted to dry, was placed in a shallow pan to a depth of several inches. Crystalline KCl was placed in a fine band across the center of the pan 0.25 inch below the soil surface. By means of an atomizer, the soil was maintained in a moist condition for a period of one month.

Two days following treatment, samples to the depth of the soil mass were taken at points 2, 4, and 6 inches from the line of application of the fertilizer and analyzed for exchangeable potassium. Additional samples were similarly taken for analysis at 6, 8, 13, 16, and 27 days following treatment.

The data resulting from this study are shown in Figure 1. They reveal a comparatively rapid movement of K away from the point of application. Some fertilizer K was found to have moved 6 inches in as many days. By the end of the test, the level of potassium 6 inches from the line had risen from the initial value of 75 up to about 3,000 ppm. In a parallel experiment, with $KHCO_3$ as the carrier (Figure 2), the movement of K was very much slower than with KCl.

The full implications of the movement of applied K in soils of the type studied are not presently assessable. The results appear to indicate that applied K may be lost to the crop independently of leaching so long as the soil remains wet, which is the normal condition of this soil in the field; at least the results suggest that K does not long remain at the point of application, a phenomenon which might well be anticipated from theoretical considerations.

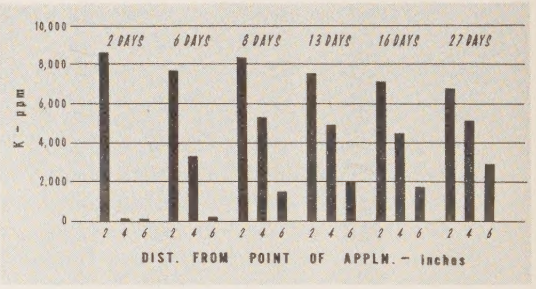


FIGURE 1. *Lateral diffusion of KCl in Puna soil (K-75 ppm).*

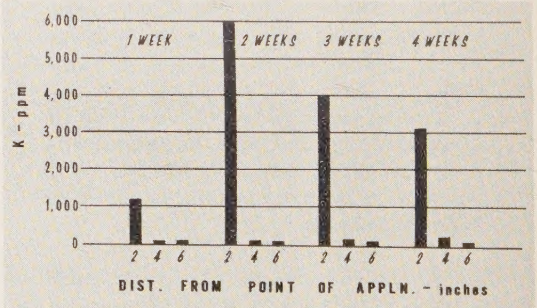


FIGURE 2. *Lateral diffusion of $KHCO_3$ in Puna soil (K-75 ppm).*

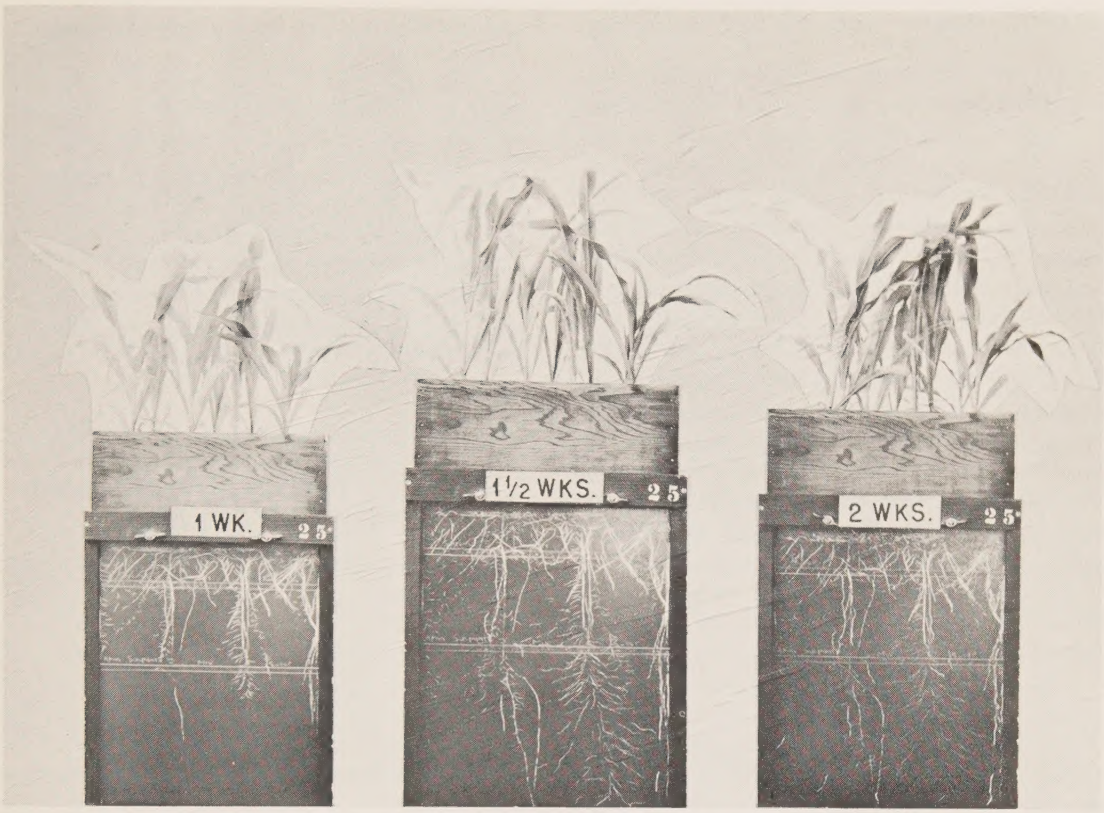


FIGURE 3. *Roots develop through fertilizer bands (ammonium sulfate band is at left of box, superphosphate band at right, and mixed band in center).*

root development not affected by fertilizer bands

Evidence from fertilizer experiments in certain Midwestern states indicates that roots proliferate upon encountering a band of NP fertilizer. The stimulative effect of an NP band on roots occurred when the N component was ammonium, but not with nitrate sources. Neither N nor P, banded alone, stimulated extra root development at the site of application.

In Hawaii, the various fertilization practices for sugar cane at time of planting include placing NP fertilizer in the line, as well as independent applications of N and P. Practically all of the N is in ammonium form as urea, ammonium sulfate, or ammonium phosphate.

To determine if cane root development was influenced by banded fertilizer, the window-box technique was used to observe the behavior of cane roots upon encountering fertilizer bands (Figure 3). Fertilizer bands placed in the soil consisted of ammonium sulfate alone, superphosphate alone, and a combination of these salts. In none of several different soils investigated was there any evidence of root proliferation, even in the NP bands. This finding, however, in no way should detract from the importance of early fertilization. The stimulative effect on growth and tillering from applications at planting has been amply demonstrated; moreover, an adequate nutrient supply at the start enhances subsequent development of roots.

liming enhances nitrogen mineralization

Transformation of soil organic N to mineral forms (nitrate and ammonium) was greatly accelerated over a 12-month period by limestone additions to Laupahoehoe and Onomea soils. As shown in Figures 4 and 5, maximum accumulation of mineral N occurred at the highest rate of liming. The results suggest that rates of liming corresponding to current practice (1 to 2 tons CaO equivalent per acre) would not influence appreciably the N nutrition of a cane crop. With heavy rates of liming, however, it is clear that the extra N released should be taken into account in the N fertilization schedule. The gradual decline in juice quality found to accompany increasing rates in certain experiments probably is associated with enhanced N mineralization.

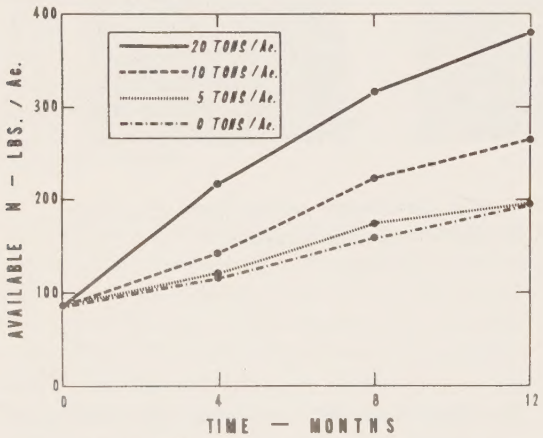
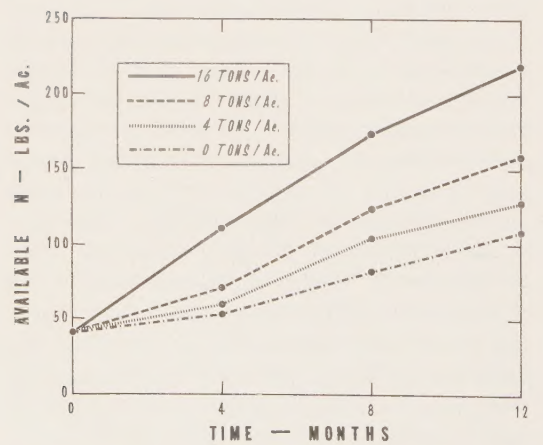


FIGURE 4. *Liming increases nitrogen mineralization in Laupahoehoe soil.*



◊ FIGURE 5. *Liming increases nitrogen mineralization in Onomea soil.*

measuring uptake of soil phosphorus

The amounts of P extracted from several soils by the modified Truog reagent (.02 normal H_2SO_4) correlated well with the uptake of P by plants, as shown in Table 2. These data provide direct evidence that the chemical procedure being used for assessing the P status of Hawaiian sugar cane soils does indeed provide a reliable measure of the relative capacities of soils to supply P to the crop.

TABLE 2. *Short-term phosphorus uptake correlates with soil analysis.*

Soil	Truog P	Phosphorus		
		Sand	Sand+Soil	Soil
	ppm	µg	µg	µg
Hilo	11	455	470	15
Kohala	99	455	580	125
Waialua	430	455	1940	1485
Makiki	1300	455	2830	2375

The procedure for measuring P uptake is of particular interest in that its use is being extended to other areas of research. For example, an exploratory study was made on the availability of applied P fertilizers in relation to type of soils. The curves in Figure 6, showing wide variations in P uptake from three soils in relation to applied P, were obtained from the following procedure:

1. Superphosphate was mixed with the soil, placed in a 12-ounce waxed cardboard container, moistened to field capacity, and allowed to react for two weeks.

2. Sudan grass, supplied with all nutrients except P, was grown for a two-week period in a bottomless cardboard container of silica sand.

3. The sand culture then was placed upon the soil-fertilizer system for one week, during which time roots permeated the soil and extracted P. Total P uptake in plant tops then was determined.

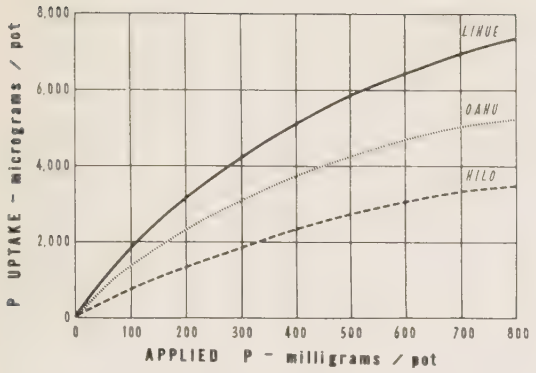


FIGURE 6. *Variations in phosphorus uptake for three different soils.*

The recovery of applied P by plants differed appreciably among soils, evidently reflecting the wide range in capacities of these soils to convert soluble phosphate to less soluble, less available forms. These results are in general agreement with earlier studies on the P-fixing capacities of Hawaiian soils, as measured by chemical extraction.

emphasis placed on soil testing

During the year, 2,115 soil samples received from plantations were analyzed for pH, P, K, Ca, and, in some instances, Mg. This represents an increase of 30 per cent over the number of samples received last year. The reliability of soil analyses for assessing the relative fertility status of soils and predicting fertilizer need rests on an impressive background of field experimental results from which crop response-soil test calibrations were derived.

Results from additional field tests this year further support the validity of the soil-testing approach to determining soil fertility status. Of twelve amounts-of-P experiments harvested during the year, only one showed response to P fertilizer. This soil was critically low in P (25 pounds per acre). Levels of soil P in the eleven remaining experiments ranged from adequate to questionable, according to the relationship established in previous calibrations.

Two amounts-of-K tests, on areas critically low in K, showed significant responses to potash application. Figure 7 presents an up-to-date compilation of all available data relating exchangeable soil Ca to increase in sugar yield resulting from application of Ca-bearing materials. Based on these data, some refinements have been made in liming recommendations based on soil tests.

No method of soil testing has yet been used for predicting the need of sugar cane for N fertilization. Preliminary studies on plantation soils have revealed a wide range, both in the quantity of residual available N from previous N applications and in the capacity of soils to release or mineralize N from the soil organic matter. A unique laboratory method for determining mineralizable N has been developed. Several rates-of-N experiments have been installed and others will be initiated during the coming year. The possibility of relating response from N fertilization to measurements of soil N, as an additional tool for predicting N fertilizer needs of sugar cane, appears promising.

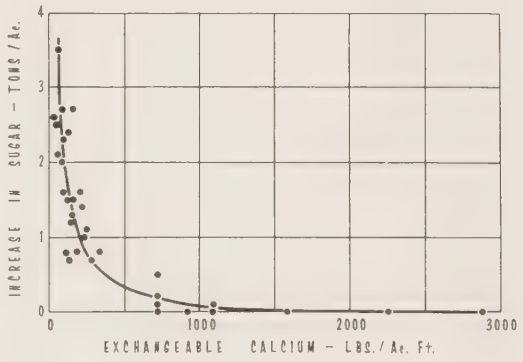


FIGURE 7. *Increase of sugar yield in response to exchangeable calcium.*

further evidence of nutrient losses by leaching

Loss of N and K by leaching often is regarded as a problem of major economic significance in heavily irrigated or high rainfall areas of Hawaii. In light of recent evidence, this broad generalization may be questioned. Results obtained from HC&S lysimeters and reported in the 1960 Annual Report showed that N losses under a ratoon crop were very small as compared to those under the plant crop. In 1961, analysis of leachates from the plant crop during the initial five-month period again reveals substantial N losses. Also in agreement with 1960 results, the presence of plant-crop root residues has resulted thus far in very small N losses from the ratoon. The retention of N logically is accounted for by microbial turnover of N during decomposition of the root and plant residues.

During the past year, determinations of the quantity and distribution of ammonium and nitrate N in a number of soil profiles have revealed the presence of rather large amounts of residual nitrogen derived from previous fertilizer applications. In some instances, for example, as much as 300 to 400 pounds of mineral N have been found to a depth of 4 or 6 feet. More commonly, amounts have ranged from 100 to 300 pounds. In some cases, one-half or more of the residual N has been concentrated in the upper 2 feet. Such studies are being continued and should contribute to better understanding of the N leaching problem and its impact on fertilization practices.

The problem of K retention in soils involves quite different considerations, for K is not subject to immobilization in the soil by the same mechanisms as N. A survey now is under way to study the distribution of residual K remaining in the soil profiles from previous fertilizer applications.

old roots lose activity after ratooning

A young sucker plant of 37-1933, transferred on January 8 into culture solution in a glass tube 4 inches in diameter and 4 feet long, developed rapidly for the next two months, the fast-growing roots elongating about 1 inch per day.

On March 8 the transfer was made, as shown in Figure 8, by pulling enough roots out of the tube to permit immersion of the stubble and upper roots in a glass crock. The old roots were not damaged by the transfer and continued to grow rapidly in the glass tube; meanwhile new roots developed in the crock.

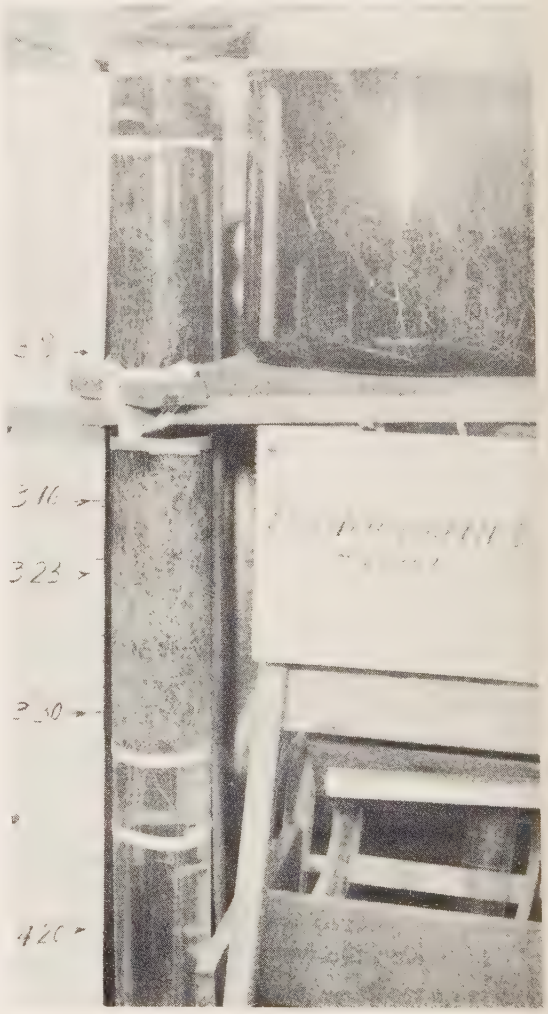


FIGURE 8. *Healthy roots in tube and crock on day that primary and secondary stalks were ratooned.*

TABLE 3. *Water consumed by ratoon. The crock contained all newly developed roots; the tube only old roots.*

Date	Water cc per day	
	Crock	Tube
Apr. 19, day before ratoon	3125	1750
Apr. 20, ratooned		
Apr. 27	450*	0
May 8	550	0
May 19	835	0

**New roots and shoots present*

On April 20 the stalks were cut off just above the water line. Table 3 gives the record of water consumption at intervals before and after ratooning. New shoots developed rapidly and put out new roots in the crock. There was no further growth of the old roots in the tube following ratooning; they took up no more water and the quick darkening indicated rapid deterioration (Figure 9).

Color photographs taken on May 1 showed clearly the changes following ratooning.

The plant took up neither water nor nutrients. To prove the complete lack of old root activity, a strong dose of P-32 was added to the tube as soon as new shoots had developed. Geiger counting of the roots above the water, as well as new growth in the stool, gave zero counts. Yet 0.5 cc of the water in the tube gave 3,925 counts per minute when dried in a planchet. This demonstrates the complete lack of any movement by capillarity or otherwise through the old roots in the tube.

Similar effects of defoliation of sugar cane seedlings are shown in Figure 10.

FIGURE 9. *New stool growth 7 weeks after ratooning. Note dead roots of primary in tube.*

FIGURE 10. *Left to right: (1) healthy roots of control plants; (2) roots of defoliated plants 3 weeks after ratooning; (3) dead roots of ratooned plants 3 weeks after ratooning.*

available water affects nitrogen uptake

As a supplement to the Waipio Irrigation Test, tagged nitrogen (N15) studies were begun on February 16, 1961, when the cane was 7.5 months of age. The cane had received 100 pounds of N per acre 4.5 months earlier, when the additional 100 pounds per acre of tagged fertilizer was applied. Two figures (11 and 12) show strikingly the effects of the moisture deficit in the A treatments, which had received only four rounds of irrigation, as compared with the adequate level of 10 to 11 rounds.

The increasing amounts of N15 found in leaf punches following fertilizer application are shown in Figure 11. With inadequate moisture the uptake is so much slower that two months after application the leaf punch nitrogen has about 40 per cent as much new fertilizer in it as in the well-watered leaves.

This slowness of uptake is reflected in residual available nitrogen found in the soil (Figure 12). The low-moisture soil has about 18 ppm more N than the well-watered soil. This is due to failure of the plants to absorb the nitrogen for there is no evidence of leaching to greater depths. The values at 4 to 6 feet are identical. The difference of 16 ppm in 2 feet of Waipio soil represents about 100 pounds per acre of available NH_3 and NO_3.

climatic variations affect growth and yield responses

Light:

The maximum possible yield of many crops is ultimately limited by the total sunlight received. The Department of Physiology and Biochemistry initiated last year a series of shading experiments that will be expanded to field scale in the next few years. Makiki Shade Experiment No. 1 was done with twelve 6-line plots of 37-1933, ratooned in October 1960. At five months of age, the crop was closed in and three plots

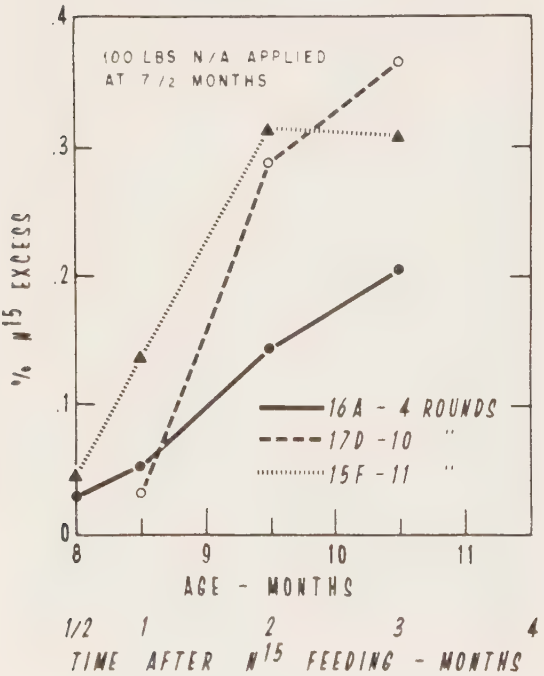


FIGURE 11. *Effect of irrigation rounds on N15 in leaf punches.*

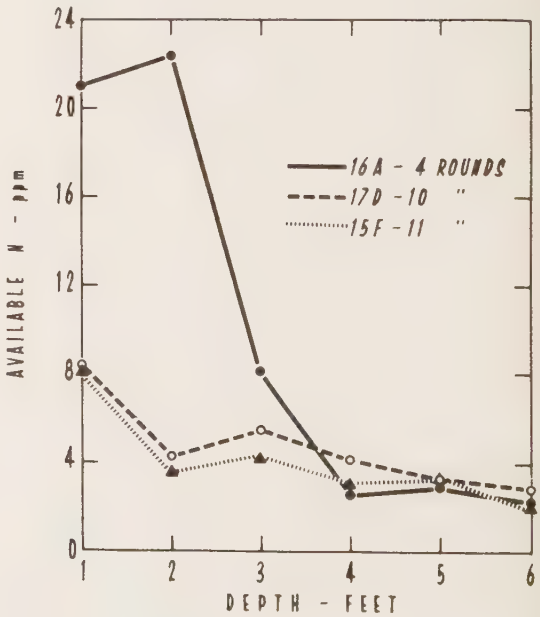


FIGURE 12. *Effect of irrigation rounds on available N in soil.*

were harvested representing zero time. The remaining nine plots were divided as follows: three with full insolation, three with 84 per cent, and three with 53 per cent. Shading was by Saran netting high enough above the cane to avoid interference with air movement. There was no drop in CO_2 content of the air under the shades. The plots were harvested three months later and the gain in dry matter calculated. Figure 13 summarizes the basic information. It shows that the crop could have used much more than full sunshine and that any reduction of light below that at Makiki, an area of very high insolation, causes a decrease in yield. The range of light covered by this experiment represents that found in sugar fields from one locality to another and from season to season (mid-winter sun is about 60 per cent of mid-summer sun).

Analyses done on these plots brought out the following:

Increasing shade increases: (1) stalk length and leaf area; (2) leaf chlorophyll, moisture, and N; (3) stalk moisture, N, K, and reducing sugars.

Increasing shade decreases: (1) total dry weight of plant, leaf thickness; (2) stalk P, sucrose, juice purity, and sucrose/RS ratio. Table 4 gives the average effect on leaf punch analyses and Table 5 the effect on the millable cane at eight months of age.

Although the cane had been subjected to reduced light for only three of the eight months since ratooning, it had been greatly retarded in development and all properties of juvenile succulence retained: high moisture and high reducing sugars; low solids and low sucrose. The sucrose:reducing sugar ratio was cut to less than half.

TABLE 4. Effects of insolation on young cane growing in deep soil with 400 lbs. N/acre and weekly irrigations. Average of analyses from March 28 to May 16 on 3-6 leaf punches.

	Per cent of full daylight		
	100	84	53
Nitrogen, %	1.95	2.01	2.11
Chlorophyll, %	0.98	1.14	1.31
Moisture, %	71.2	72.2	73.5

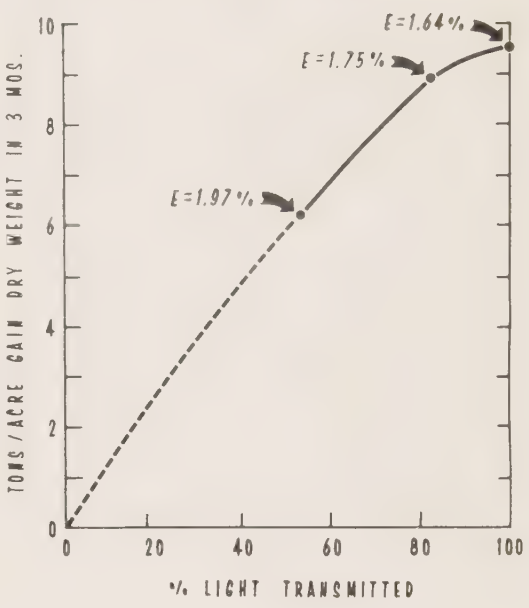


FIGURE 13. Light intensity and sugar cane production. Gain in dry matter by a closed-in crop of 37-1933, age 5 to 8 months. (Feb. 21 to May 22, 1961. Full sun-52817 cal/cm². Mean temperature 76 F.

TABLE 5. Effect of insolation on millable cane at 8 months of age. Variety 37-1933, 400 lbs. N/acre.

Treatment	Juice			Cane			Sucrose :RS
	Solids	Pol	Purity	Fiber	Pol	Moisture	
Full sunlight	14.4	10.8	75.2	12.3	9.5	75.1	6.6
84% "	12.6	8.0	63.3	10.7	7.7	78.1	3.1
53% "	12.5	7.4	59.3	10.1	6.7	78.6	2.8

Soil temperature:

The study of field soil temperatures with respect to location of plantation, elevation, and season of the year has been continued. Data have been obtained from thirteen plantations representing over 100 stations where from three to five readings per station were made. These data have added greatly to our knowledge of soil temperatures prevailing throughout the sugar cane growing areas in Hawaii. They will be of particular value in assessing the reasons for the poor growth of sugar cane in certain areas.

In some sugar cane fields, more particularly on irrigated plantations, soil temperature measurements have shown that the soil temperature was not sufficiently low to be the cause of poor growth, as has been erroneously believed in the past.

Soil temperatures in the wet mauka fields of most of the unirrigated plantations do play an important role in germination and rate of growth. This is brought about either by the inability of the sugar cane to take up plant food or by slowing the metabolic processes of the plant in general.

Data obtained during the year 1960-1961 may be summarized as follows:

1. In general, as the elevation of the fields increases, the cooling of the soil averages about 1°F. per 225 to 300 feet.
2. The difference between winter and summer temperatures at the depth of maximum root concentration is less than was generally believed. It amounts to from 3° to 6°F., the smaller differences prevailing at the higher elevations.
3. The lowest soil temperature measured on sugar cane land was 61°F. at an elevation of 3,000 feet. This was the winter temperature and extended from the surface to at least a depth of 30 inches in a dense stand of sugar cane and trash. The summer temperature at this same location was 64°F.
4. In many fields local conditions greatly influence the soil temperature, causing them to be warmer or colder than expected for a given elevation. This may be brought about by direction of exposure, angle of slope, lack of air drainage, and extent of cloudiness.

Gibberellic acid (GA):

Previous work has shown that, whatever the mode of application of GA, the effect on elongation starts with the No. 4 joint. The number of younger joints affected and the degree of elongation depends upon the quantity of GA absorbed by the cane plant.

The effect of this excessive elongation on cane quality and pol yields was determined on 12 stalks each of varieties 37-1933 and 44-2772 which had received an additional 200 pounds nitrogen per acre at four months of age. Half the stalks were treated with 10 mg of GA per stalk at the dewlap. All were harvested when the joints, which were Nos. 1-4 at time of treatment, were visibly mature. The results given in Table 6 show the great gain in pol and fiber of the sensitive joints (1-4). The treated joints are approximately double the controls in size and there is no drop in pol: fiber ratio.

TABLE 6. *Effect of gibberellic acid (GA) on cane and pol weights.*

Variety and Treatment	Joints No. 5-8	No. 4-1	No. 01-04*
Grams pol			
37-1933+GA	62.48	101.73	33.59
Check	54.40	49.16	32.14
44-2772+GA	76.14	121.65	61.84
Check	68.96	65.84	58.54
Grams fiber			
37-1933+GA	57.94	105.51	36.32
Check	49.65	48.20	32.85
44-2772+GA	55.46	90.34	45.56
Check	60.21	46.15	43.37

* *The zero before the joint number designates joints grown after application date*

The data in Table 6 may be translated into yield effects as follows: with four stalks per foot of line and a single spray of 10 mg GA per stalk during the boom stage of growth, the yield could be increased by 1.8 tons pol per acre.

Absorption and translocation of Versene:

The chelating agent, Versene, inhibits flowering of sugar cane fairly well. It is of interest to know how this chemical brings this about. Versene tagged with radioactive carbon* in the ethylene diamine portion of the molecule was applied to the lamina at about the mid-section of blade No. 6, radio counts were made of the cane tissues at different times after the application, and the following results were obtained:

1. Five hours after application, the movement of Versene was still all toward the tip of the blade, indicating xylem transport.
2. Forty-eight hours after application the whole blade was radioactive, but translocation of Versene out of the blade and sheath was very small. Radio counts indicate that movement out of the treated leaf is through phloem, the two cane joints below the leaf being the most active while blades other than the one treated showed no radioactivity.
3. Seventeen days after application the whole top of the stalk above No. 8 joint, but excepting the blades, is more or less radioactive; still, only 1.05 per cent of the absorbed Versene has moved out of the treated No. 6 blade.

This would indicate that the inhibition of flowering takes place in the leaves themselves, possibly by suppression of the flowering hormone. Versene resembles CMU in its failure to be translocated from the absorption site.

Translocation:

Using techniques described in previous reports, the movement of photosynthate has been followed by feeding radioactive carbon dioxide ($C^{14}O_2$) to illuminated leaves and finding the percentages of newly-made tagged sugars which are present in various tissues after a certain time has elapsed. The following tentative conclusions have been reached concerning translocation in intact plants:

All blades translocated higher percentages of photosynthate in the morning than in the afternoon.

Very young blades (No. 3) and old blades (Nos. 11,12) translocate smaller percentages than medium blades (No. 7).

Translocation is not affected by gravity.

Translocation is not affected by transpiration, although it is regulated by turgor pressure and moisture conditions.

Darkening of the entire plant increases downward translocation and decreases upward translocation.

Darkening the fed blade decreases translocation from that leaf only; therefore, continued photosynthesis aids translocation of sugars already formed, a "washing out" effect. Similarly, cutting off the blade above the fed part decreases translocation from the fed leaf. Again, prevention of photosynthesis above the fed part removes the "washing out" effect and thus decreases translocation.

Actively growing lalas and suckers constitute sinks and increase the percentage translocation downwards. The importance of a sink is also shown by comparing translocation in a detached blade with that in a blade attached to a four-joint length of stem.

In expressing sugar into the stem, a leaf must compete with the leaves above it. Removing top leaves removes competing streams, thus enabling the fed blade to export a larger percentage of its photosynthate. Removing bottom leaves has no effect.

Translocation in a blade, attached or detached, is polar, being almost entirely basipetal. The polarity is not affected by gravity. Water and dissolved substances, however, can move in either direction in a blade with both ends cut, depending upon the direction of the pull of transpiration.

Translocation mechanism can be damaged during feeding by high insolation, probably an effect of temperature rather than light.

Translocation is increased by continued photosynthesis at the source and by supplying a sink. It is definitely polar; is increased by removal of competing streams; is damaged by high temperature; does not require light; is not affected by gravity or transpiration; therefore, translocation is a living, active process, probably a mass movement regulated by turgor pressures and suction forces, which are in turn dependent upon life.

* *We are indebted to The Dow Chemical Company for this sample.*

How translocation follows the vascular bundles, with very little cross transport, is illustrated in Figure 14. The high radioactivity flows directly below the fed lamina (white spot) and, since the sheath wraps completely around the stalk, the opposite side of the stalk receives almost all the sugar. This explains the crossing-over effect that has been observed earlier with P32.

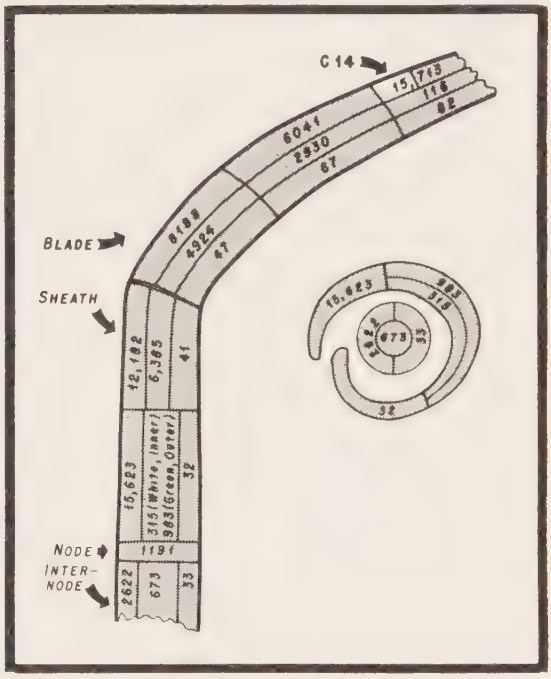


FIGURE 14. *Translocation for 100 minutes from one fed lamina. Left: relative specific activities. Right: approximate relative positions of internode and lower sheath.*

The comparative translocation of ten varieties in the Makiki plots is shown in Table 7. The comparative translocation of blades 3-8 is shown in Table 8. The presence of suckers and lalas has a marked effect upon the translocation from older leaves. They serve as a sink and probably derive nutrients from the parent plant (Table 9).

Translocation within detached leaves is proving to be of great interest. The rate is of the same order as in the intact plant. It is not a general diffusion but follows the vascular bundles just as in the intact plant. It is polar, always going to the base of the leaf no matter which end is in the beaker of water; hence, the phloem transport is independent of the direction of the transpiration streams. The tagged sugar is translocated to the cut end without more than a trace entering the water itself (Table 10). All results point to the fact that the driving force of translocation is within the leaf itself.

Potassium deficiency:

Plants made highly deficient in K after growing some time in culture solution free of K were fed P32 for a period long enough to set up a steady state among the phosphorylated compounds. At harvest the tissue extracts were analyzed and chromatographed. The results show two important effects of K deficiency:

TABLE 7. *Percent translocation from fed blade No. 4 in 10 varieties at Makiki.*

Variety	August 26, 1960				May 3, 1961
	5 hrs.	24 hrs.	29 hrs.	96 hrs.	90 min.
39-3633	64.8	94.6	95.6	97.3	58.7
32-8560	76.4	94.9	96.0	97.6	47.3
H-109	74.5	93.7	94.5	97.2	20.7
49-5	65.4	92.0	94.7	98.5	50.0
49-104	66.6	91.5	95.3	98.3	42.8
37-1933	63.8	94.6	95.4	98.5	44.9
38-2915	63.9	93.8	96.0	98.7	46.4
39-7028	74.8	93.0	95.5	98.0	72.7
44-3098	78.3	95.2	96.5	98.6	67.1
44-2772	78.2	93.3	95.4	98.0	21.9
Ave. 10 var.	70.7	93.7	95.5	98.1	47.2
Spread	14.4	3.7	2.0	1.5	52.0

1. The important intermediate PGA (phosphoglyceric acid) is almost entirely lacking and the P remains in a soluble inorganic form.

2. The synthesis of sucrose from reducing sugars is greatly suppressed, changing the S:RS ratio from 2.4 to 0.37.

These plants were in a state of very severe deficiency, however it is possible that mild deficiency would induce the same effects to a lesser degree.

TABLE 8. *Percent translocation from blades 3-8 of the same stalk.*

Blade No.	90-minute period A.M.	P.M.	24-hour period
3	47.6	22.2	89.9
4	51.8	26.5	90.6
5	44.1*	15.4*	90.3
6	50.7	31.4	91.9
7	64.4	22.2	95.0
8	57.1	34.2	93.5

* *Short longitudinal split below fed part*

TABLE 9. *Effects of lalas and suckers on translocation for 2 hrs. from fed blade No. 6. Percent of total counts.*

Suckers	Lalas	Translocated from fed leaf
0	0	16.4%
0	+	38.1%
+	0	46.3%
+	+	48.5%

Ave. 0 suckers	27.2	Ave. 0 lalas	31.3
Ave. + suckers	47.4	Ave. + lalas	43.3

TABLE 10. *Translocation for 24 hrs. in a cut blade.*

Part*	Length, cm	% of counts
A2		0.17
A1	15	0.09
Fed	20	33.72
B1	8	8.09
B2	10	10.45
B3	10	11.41
B4	10	13.71
B5	10	13.28
B6	10	9.07
Water		0.01

* *A = above feeding site; B = below*

Intermediates of photosynthesis:

Organic acids containing only one radioactive carbon atom were fed to sections of cane leaves. When the interchangeable 4-carbon acids, aspartic or malic, were fed, one-half of the radioactivity was found in sucrose after one hour regardless of which carbon atom was labelled. This shows that malic acid is actually converted to sucrose, and is not simply a carrier of carbon dioxide.

One-fourth of the activity of glucose formed from malic acid labelled on the third carbon atom was found in carbon No. 6, an end carbon atom of glucose. This proves that malic acid is broken up before sucrose synthesis.

As expected, only a small amount of ketoglutaric acid was converted to sucrose, showing that the Krebs cycle is not involved.

The effect of the inhibitors malonic acid and cocaine was tested. Although the synthesis of malic acid from oxalacetate or glyoxylate is said to be prevented by malonic acid or cocaine, respectively, both were effective so no conclusions can be drawn. Both reduced the amount of sugar phosphates very strongly.

Malonic acid reduced total photosynthesis to 11 per cent of the control, but sucrose only to 37 per cent. PGA and malic acid were both reduced to 12 per cent of the control. In algae, malonic acid decreased malic acid synthesis greatly, and this has been taken to mean that malic acid was not involved in photosynthesis. Obviously, this is not true for sugar cane.

Sugar deposition:

Radioactive carbon (C14) is the only tool by which it can be determined where photosynthate goes and how long it remains in a tissue. The first long-term study was reported in the 1960 Annual Report. Stools of 37-1933 were tagged by clamping a tight photosynthesis chamber over a portion of one leaf, injecting $C^{14}O_2$ for a period of 15 minutes in bright light. All the photosynthate made during that 15-minute period is radioactive and its location can be

determined at any future date. There is a certain amount of metabolic exchange and reshuffling of the C14, but the results indicate that the major portion is quickly divided between carbon for tissue building and carbon for sucrose storage. Last year's results established that old primaries and very young suckers follow identical patterns:

1. Sugar from the younger leaves builds fiber in the younger joints.
2. Regardless of leaf fed, the 8-10 joints retain permanently the greatest amount of sucrose made on a given day. These joints are in the middle of the transition from succulence to maturity.
3. Appreciable amounts of sucrose made daily are stored in older joints.
4. Practically none of the stored sugar is drawn upon to build new tissues formed after the feeding (joints 0 to 010).

A new experiment recently harvested was done with stools of 37-1933 grown from single-eye seedpieces. The cane was 8.5 months of age when fed and 14 months at harvest, when there were nine secondaries and seven third-order stalks. A portion of the 6th blade of the primary was fed $C14O_2$ for 10 minutes in bright light.

At harvest, the entire stool was recovered. About 5 per cent of the radioactivity was found in the secondaries and tertiaries which made up 95 per cent of the total stool weight. Hence, there is considerable circulation throughout the stool although the major portion of each day's photosynthate remains fixed in a few tissues of the leaf's own stalk.

Recovery of nitrogen:

Sugar cane plants were heavily tagged with N15 by feeding N15 ammonium sulfate in water culture over a period of time long enough for the N15 to have been thoroughly incorporated into all the nitrogen compounds of the tissues. These plants were harvested, and divided into three parts: leaves, stalks, and roots (including stubble). These were dried and ground before incorporation into the soil; their analyses are given in Table 11. Analyses of the Makiki soil used for the study showed pH 7.0, 385 ppm P, 455 ppm K, and 1.1 per cent carbon.

Since the cane organic residues have such high carbon:nitrogen ratios, it was necessary to add inorganic N to prevent complete starvation of the cane. The schedule of treatments is given in Table 12. Since the cane tissues contain different percentages of N it was necessary to add different amounts to each pot of soil to furnish the 100 pounds N per acre from each. These quantities

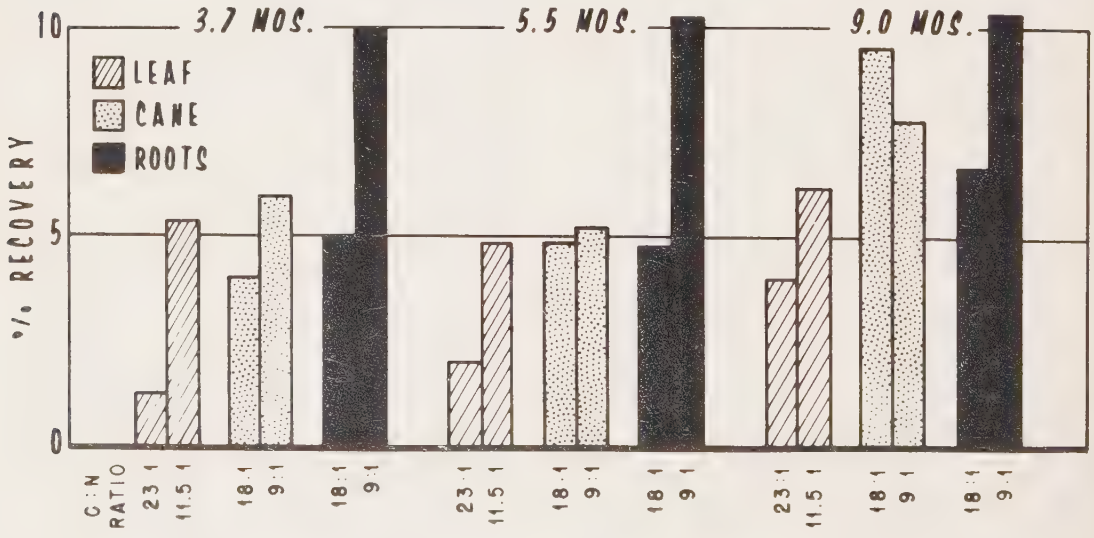


FIGURE 15. Relationship between C:N ratio and N recovery from tissues of a cane plant.

were 2.9, 4.1, and 3.8 tons trash per acre of leaf, root, and stalk, respectively.

The results summarized in Figure 15 are calculated from the recovery of N15 in the plants growing in the soils containing the trash. The following conclusions may be drawn:

1. Root nitrogen is more readily available than that from either leaves or stalk.
2. Low C:N ratios favor the uptake of N from organic sources.
3. The low total recovery (10%) after 9 months may be due to the poor penetration of roots into these soils under pot conditions.

split root technique contrasts root response to low moisture and low fertility

The root system of a cane plant can develop normally even if only a portion of the roots encounter well-fertilized soil. This was demonstrated using a split-root technique in which portions of the roots from a single plant developed simultaneously in unfertilized quartz sand and in a well-fertilized soil. Since normal root development occurred in the infertile sand, it appears evident that nutrients were supplied to these roots by the remainder of the plant, again demonstrating the dynamic nature of nutrient transport and equilibration within the cane plant. The practical significance of such findings is at once apparent, for much of the Hawaiian cane crop receives fertilizer in localized surface applications; moreover, the subsurface layers of many Hawaiian soils are extremely low in available nutrients.

In contrast, split-root studies show that roots which encounter extremely dry soil (below the permanent wilting point) do not develop, even if the remainder of the root system is adequately watered. This is evident in Figure 16.

light meters under test

The almost linear relation between insolation (solar radiation) and dry matter production in a closed-in field of sugar cane makes light records of great value in estimating potential productivity of different areas. There are now three HSPA integrating pyrheliometers which serve as standards. At least three more should be placed in strategic locations in cane-growing areas; in addition, there is a need for records in many individual fields.

The photochemical method developed at the Station some years ago is reliable

TABLE 11. *Analysis of cane plants tagged heavily with N15.*

	% C*	% N*	C:N	Atom % N15 Excess
Green cane leaf	45.26	1.30	35:1	2.60
Cane stalk (no leaf	45.20	1.65	27.4:1	1.87
Cane roots	32.28	1.20	27:1	1.92

** Results are expressed on dry-weight basis*

TABLE 12. *Schedule of treatments with organic materials.*

Treatment	Lbs. Nitrogen per Acre			Added as $(NH_4)_2SO_4$	Total Lbs. N/Acre	C:N Ratio
	Cane Leaf	Cane Stalk	Cane Roots			
Organic	100			50	150	23:1
Organic		100		50	150	18:1
Organic			100	50	150	18:1
Inorganic	50			100	150	11.5:1
Inorganic		50		100	150	9:1
Inorganic			50	100	150	9:1
Controls				150	150	---

but requires weekly titrations which are time consuming.

The phototube-electronic sunlight integrators developed by Kentron under contract with the HSPA are being tested. Many of the 24 which have been manufactured to date did not meet specifications under prolonged test. The test site is shown in Figure 17. Six have been accepted and are being checked in several localities.

Figure 18 shows the HSPA-Tracerlab radioactive sunlight integrator. The prototype has been under test at the Station for some months and is performing well.

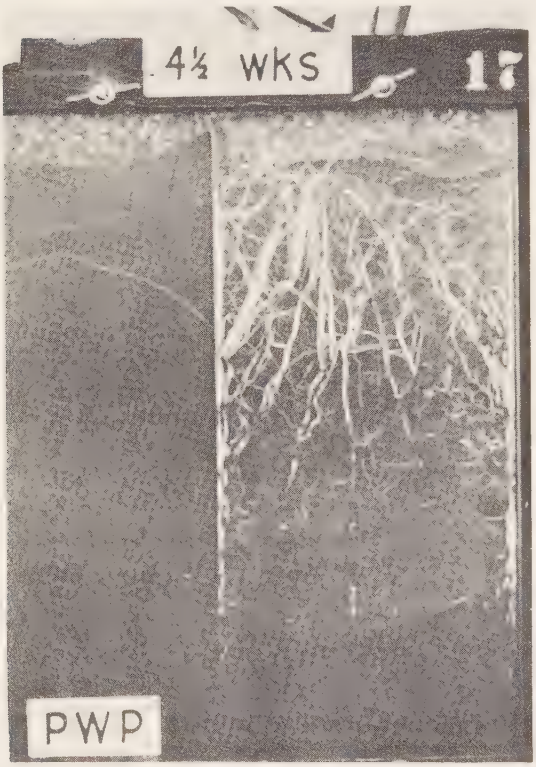


FIGURE 16. *Cane roots develop in the soil which is moistened daily, but fail to develop on the other side where soil moisture was adjusted to the permanent wilting percentage.*

FIGURE 17. *Fourteen Kentron sunlight integrators being calibrated. In background, other types of measuring instruments are being tested.*

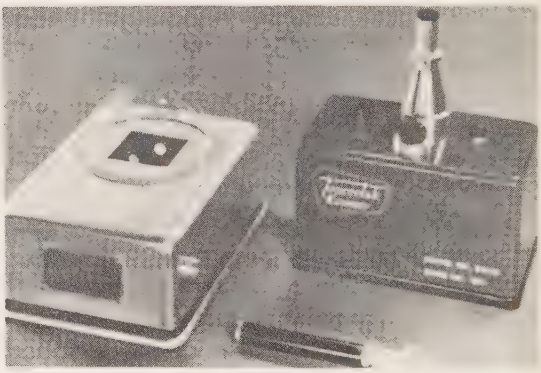


FIGURE 18. *HSPA radioactive integrating light meter (manufactured by Tracerlab, Inc.).*

DISEASES

varietal resistance trials in fiji

Thirty additional Hawaiian varieties were sent to Fiji in September 1961 and are being grown under field quarantine for one year, following which 28 of them will be included in replicated varietal resistance tests. Two varieties are being reintroduced to Fiji to determine whether the decline in growth of these varieties from the first introductions may have been due to growing them under unfavorable environmental conditions.

The results from the downy mildew test in 1961 were rather erratic; check variety 49-118, which is rated as being moderately susceptible, did not contract the disease. Fourteen of the varieties in this test, showing less than 30 per cent infection, will be retested.

Satisfactory results were obtained from the first ratoons of the Fiji disease trials Nos. 7B, C, and D planted in March 1959. The final grades assigned to the varieties in these tests, together with tentative ratings for downy mildew, are shown in Table 13. The varietal ratings from these tests indicate a greater susceptibility for the later numbered varieties, although the numbers are too small for significance.

molokai quarantine

Twenty-one varieties from Beltsville, Maryland and Canal Point, Florida, were introduced to Hawaii during the past year through the USDA, and are growing in the small quarantine house at Mapulehu, Molokai. These will be released to the quarantine field in October. Nineteen varieties completed the quarantine period in the field at Mapulehu in October 1960 and were released and sent to the Kailua Substation. Fourteen varieties were transferred to the quarantine field from the small greenhouse.

No insects or diseases foreign to Hawaii were observed on these varieties during their quarantine period.

TABLE 13. *Varietal ratings for resistance to Fiji Disease (FD) and Downy Mildew (DM)*

VARIETY	FD	DM
46-3037	--	--
48-3845	+	=
50-2016	=	+
2524	++	-
2895	+	-
3601	++	+
6062	=-	=
51-703	-	=
2279	=	--
3049	=+	=
4212	=	+
4448	+	-
5017	=	--
6238	=-	--
52-3157	-	-
3205	-	=
3678	=-	=
4511	=-	--
5165	=	--
53-779	=-	++
54-182	-	--
366	--	=

+values designate resistance;
-values designate susceptibility.

TABLE 14. *Varietal resistance tests against Ratoon Stunting Disease*

Variety		Yield Reduction Tons Pol/Acre
TEST 1		
37-1933		4.5
39-4753		2.4
41-3340		2.4
44-2772		3.0
3098		5.4
48-4646		1.4
49-5		1.3
104		3.2
108		1.2
612		1.1
3533		0.8
3961		3.0
50-2036		6.1
7209		7.1
51-4336		2.4
	LSD*	4.9
TEST 2		
39-3633		2.9
41-1045		5.4
49-134		4.8
3404		7.7
50-723		0.4
51-3049		4.9
	HSD*	3.8
TEST 3		
44-2772		2.1**
49-5		1.8
3533		0.6
50-7209**		2.4
	HSD*	1.1
TEST 4		
46-4899		4.3
50-2542		4.0
6877		3.7
51-760		1.7
4212		1.9
8194		1.6
52-123		1.8
4511		4.5
53-1447		9.4
TEST 5		
50-2036		1.8***
51-4336		0.5***

* *Comparison within variety only*
** *Significant yield reductions in first ratoon crop*
*** *Insignificant*

ratoon stunting disease being watched

Reductions in tons pol per acre from RSD for varieties from two replicates of diseased and healthy plots grown under moisture stress are shown in Table 14.

The following varieties showed no reduction in yields from RSD: 38-2915, 39-5803, 39-7028, 45-2608, 45-2860, 46-564, and 48-4605.

Because of the lack of available land, testing was limited to two replications each of diseased and healthy plots; therefore, we do not believe these results are conclusive. Irrigation for Test 1 was about normal, while cane in the subsequent tests was placed under stress by extending the irrigation interval. Drought conditions increase the losses of varieties affected with RSD and give a better measure of resistance and susceptibility.

The apparent high susceptibility to RSD for 53-1447 points out the potential losses which may result from spreading such a variety without continued inspections of seed areas and use of the long hot-water treatment.

A Grade A varietal resistance test with variety 50-7209 was installed at HC&S to measure the losses expected when this variety is grown under normal plantation cultural practices.

Immunity to RSD is being investigated from crosses made in 1960; 500 seedlings, selected for good growth characteristics, were inoculated with RSD and will be examined for disease symptoms. If inoculated seedlings exhibit no RSD symptoms, they will be tested for the presence of the virus by inoculating healthy cuttings of 45-2120, which produces excellent symptoms when affected with RSD. Seedlings free of the disease in the preliminary test will be reinoculated to determine whether they previously escaped infection or are immune to RSD. If immune seedlings are found, they will be used in the breeding program in an effort to produce resistant varieties.

close watch kept for disease outbreaks

Inspections of sugar cane varieties on the plantations were made to assess the prevalence of cane diseases, in order to be able to recommend control measures.

Chlorotic streak disease is confined mainly to the heavy rainfall areas. Hot-water treatment of cuttings, in general use in most of these areas, is helping to reduce the losses from this disease.

Ratoon stunting disease (RSD) was found on several plantations for the first time during 1961 and variety 50-7209 on one plantation showed a high percentage of stalks affected.

Red rot disease has been of minor importance in the areas still planted to variety 38-2915. Other diseases of minor importance during the past year were: leaf scald, internal stalk necrosis, pokkah boeng, ring spot, and pineapple disease.

Internal stalk necrosis, a phyiological disease, was observed in the basal internodes of 50-7209 (Figure 19) where the variety was subjected to drought conditions.

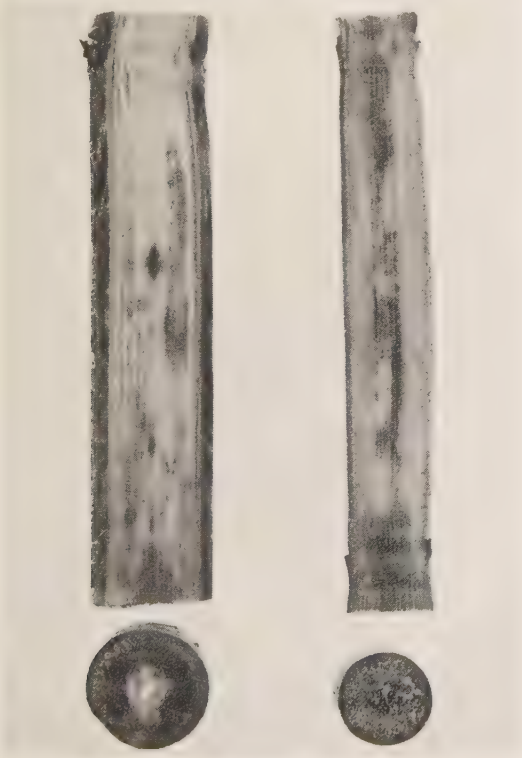


FIGURE 19. *Internal stalk necrosis in 50-7209 subjected to drought.*

checking leaf scald disease

To test the resistance of commercial and the most promising of the new varieties against leaf scald disease (LSD), 32 selected varieties plus two susceptible check varieties were inoculated with the LSD organism, *Xanthomonas albilineans*, and planted at Kailua in 1961. LSD symptoms have developed on check varieties 28-4291 and 53-3303, and in one plot of variety 54-1494. LSD has also been reported on varieties 53-4563 and 54-4023 at the Hilo Makai Variety Station and on varieties 55-1298 and 55-4540 at the Kau Variety Station.

testing for resistance to pythium

Cane seedlings:

Hawaiian commercial varieties of sugar cane vary in their degree of susceptibility to *Pythium graminicolum* and, under field conditions which favor the development of the organism (cool, wet conditions), losses in yield may occur with susceptible varieties.

To determine resistance or tolerance to *Pythium* that may exist in a seedling population, 1,000 seedlings are being tested against *P. graminicolum* in pot tests. Five weeks after installation of the tests, roots of selected seedlings showed differences in development (Figure 20), which indicate differences in tolerance to *Pythium* root rot, although *Pythium* lesions were present on the roots of all the seedlings examined. Seedlings that continue to show resistance against *Pythium* will be retested in replicated pot tests. If resistance of seedlings to *P. graminicolum* is established, an attempt will be made to retain this factor in the production of new commercial varieties.

Leading varieties:

An earlier pot test was repeated twice during the year to determine the reaction of six leading commercial varieties, 37-1933, 39-7028, 44-3098, 49-5, 49-3533, and 50-7209, to *Pythium* root rot. The tests were carried out in un-

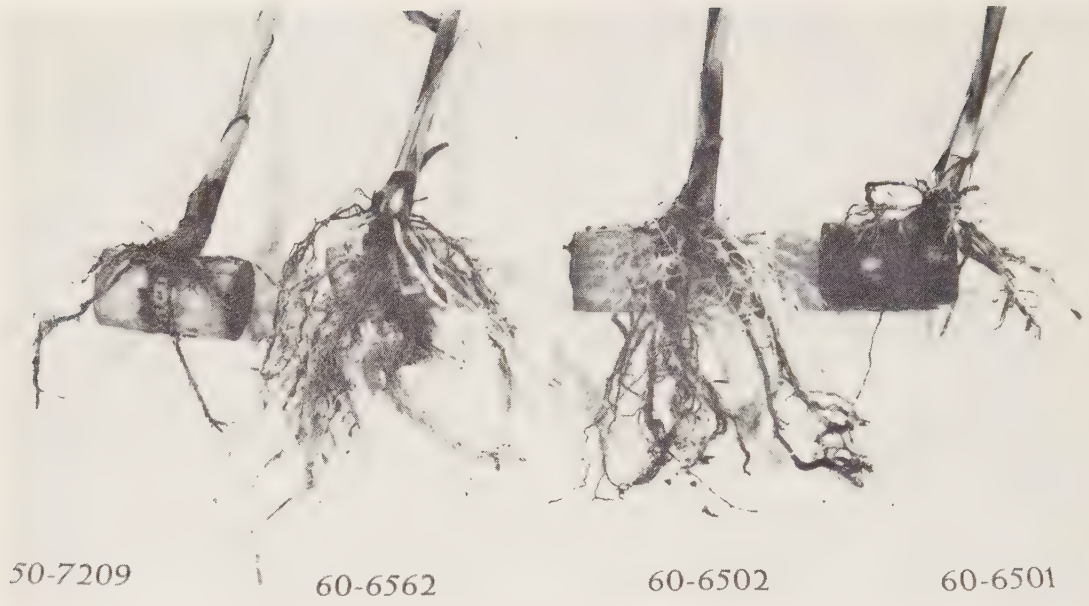


FIGURE 20. *Differences in root development for seedlings grown in sterile soil inoculated with* P. graminicolum. *The variety 50-7209 is highly susceptible to* Pythium *root rot under these conditions.*

fumigated and methyl bromide-fumigated Makiki compost soils during different periods of the year. The initial test was carried out during the period March 18 to June 27, 1960, the first repetition during August 10 to November 28, 1960 and the second repetition during the period January 18 to May 8, 1961.

Dry weights in grams of the tops and thoroughly washed roots were taken at the end of 3 1/2 months, counts of secondary shoots made, and data for the first repetition statistically analyzed. Results were essentially the same as those in the initial test in 1960. The data from all three tests will be compiled and analyzed to see whether there are significant differences in resistance to *Pythium* between varieties.

fungus used to determine level of zinc in soils

The *Aspergillus niger* method for the biological assay of plantation soils is based on the principle that, other factors being constant, the variations in the amount of growth (weight of mycelia) and growth characteristics (consistency of mycelial pads and amount and color of spores) of the test organism (*A. niger*) will be a function of the amounts of a particular trace element present in the growth medium. The Station is using this method to study the zinc content of sugar cane soils.

A standard growth curve for zinc was established by growing the fungus for 7 days at 28° C. in 50 ml. aliquots of a basal culture medium containing all of the essential nutrients, except zinc, for optimum growth of the test fungus. The dry weights of the mycelial pads were plotted against concentrations of zinc.

An assay of zinc in soils was made by placing 0.5-gram samples of air-dried, sieved soils into flasks to which 50 ml. aliquots of the basal culture medium was added together with *A. niger*.

To ascertain whether poor growth of the test fungus was due actually to deficiency of available zinc or to some toxic material in the soil, a series for each soil was included with the addition of 10 µg. zinc per 50 ml. of solution. Also investigated were the effects of varying amounts of a chelating agent, disodium ethylenediamine tetraacetate (EDTA), on the growth of the test fungus in solution with and without soils.

Soils tested to date may be grouped as follows with respect to available zinc content:

Low levels:

Hilo Sugar Co., Fields 19 and 520
Pioneer Mill Co., Field LA-5A
HC&S Co., Field 903
Honokaa Sugar Co., Field 7

High levels:

Hawaiian Agricultural Co., Field 161
Lihue Plantation Co., Field M17A
Waialua Agricultural Co.,
Field Opaeula 9
Oahu Sugar Co., Field 10B
Paauhau Sugar Co., Field F-025
Kohala Sugar Co., Field Alaalae 5A

The addition of zinc to soils of low available zinc increased the amount of growth of the fungus (Figure 21).

The addition of 0.1 per cent of the chelating agent (EDTA) in solution with soils low in available zinc markedly increased the growth of the test fungus, whereas the response from 0.5 per cent EDTA was not as great; the combined addition of zinc + EDTA to soils low in available zinc resulted in greater increase in growth of the test fungus in solution with soil of low available zinc (Figure 22). The responses of the fungus to zinc and chelating agent in soils already high on the standard curve may not be significant (Figure 23).

The A. *niger* method appears promising as a tool for pinpointing areas in sugar cane fields which may be low in available zinc and which may provide soil for pot and field tests to study the response of sugar cane to this trace element.

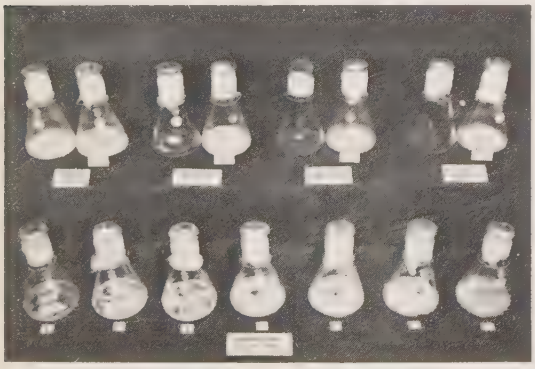


FIGURE 21. Effects of adding zinc -- note increased growth of fungus when zinc was added to soils from Pioneer Mill, Hilo Sugar, and Lanai.

fungicide practices may change for new varieties

Twenty-five chemicals were screened against the pineapple disease organism, *Ceratocystis paradoxa*, in the laboratory; none were found to be superior to phenyl mercuric acetate (PMA) for the control of this fungus. Many of the new commercial varieties germinate more vigorously than those being grown when PMA was first recommended for the control of pineapple disease attacking sugar cane cuttings. Plantations using the hot PMA treatment are advised to review their seed-treatment practice, since the newer varieties may germinate sufficiently quickly during the warmer season to permit the suspension of seed treatment or the substitution of the cold PMA treatment during this period.

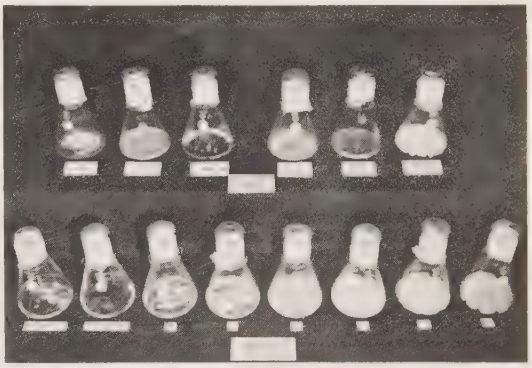


FIGURE 22. Increased growth of fungus shows effects of adding zinc and EDTA to soil of low available zinc.

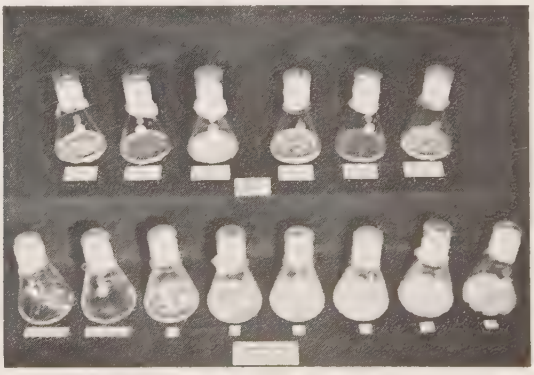


FIGURE 23. Only slight differences in growth of A. Niger are found when zinc and EDTA are added to soil high in available zinc.

will organic materials offset harmful effects of soil microorganisms?

A replicated pot test was installed during the latter part of June 1961 to determine if high amounts of organic materials of varying C:N ratios, when added to soils from a poor growth area, will result in improved cane growth by decreasing the harmful effects of soil microorganisms (especially *Pythium*)

The following materials were included at varying rates per acre:

10 tons trash at 25:1 and 12.5:1 C:N ratios
5 tons trash at 104.4:1, 25:1, 12.5:1, and 7:1 C:N ratios
5 tons trash + 1 ton molasses at 25:1 and 12.5:1 ratios
5 tons bagasse at 25:1 and 12.5:1 C:N ratios.
1 ton molasses at 37.6:1, 25:1, and 12.5:1 ratios

Nitrogen controls were included and several pots of soil were treated with a fungicide (Dexon) which has effectively controlled Pythium root rot in past pot studies.

Variety 37-1933 was planted in the pots three weeks after incorporation of the amendments. After 5 1/2 weeks of growth, the only visible differences between all treatments were the marked depression in growth and the yellowing of plants in soils treated with 5 tons of trash at 104.4:1 C:N ratio without added nitrogen.

The test will be harvested when the plants are about 3 1/2 months of age, at which time nitrogen analyses will be made of the above-ground portions of the plants to determine their N status from the different treatments.

developing laboratory methods for studying pythium

At present, there is no satisfactory method for quantitatively estimating the population or the disease potential of *Pythium* in soil. With a satisfactory quantitative method it would be possible to obtain basic information concerning the effects of soil treatments on the *Pythium* population in soil; on the rates of reinfestation of soil by the pathogen following soil treatments; and, above all, on the differences in population density or disease potentials of *Pythium* in soils from poor growth areas versus good growth areas.

Studies are under way to establish a serial-dilution method by systematically diluting field soil with steam-sterilized soil until a 1/64 dilution of the original soil is obtained. The soil is then tested by the pineapple-crown method; the reciprocal of the highest dilution showing positive *Pythium* infection of the pineapple roots represents the Disease Potential Index of *Pythium* in the soil.

Several plants in addition to pineapple are being screened as possible host plants which may be used in a serial-dilution technique; these include sugar cane seedlings and cuttings, sorghum, sudan grass, wheat, and corn. A plant which will yield dependable results in the minimum length of time would be desirable. The advantages and disadvantages of the various host plants will be studied before adopting one as a standard test plant in developing the dilution method.

nematode studies continue

With the assistance of a Shell Chemical Company Research Grant, cooperative nematode investigations with the University of Hawaii were continued. Pure cultures of four species of nematodes associated with sugar cane, (*Helicotylenchus nannus*, *Pratylenchus zeae*, *Meloidogyne incognita*, and *Trichodorus christiei*) are being tested to determine their pathogenicity against variety 37-1933.

The effects of elevation and soil type on nematode populations were studied by sampling at elevations ranging from 80 to 2,350 feet on four plantations. *P. zeae* was absent, or was found only in trace amounts, above 2,000 feet, while *Xiphinema americanum* was not found above 670 feet, indicating that the elevations of fields planted to sugar cane may be a factor in the distribution of

some species of nematodes. In general, however, the results indicate that elevation alone has little effect on nematode population dynamics.

soil fumigation tests

A fumigation test (installed in Field 101P at Hamakua and planted with variety 32-8560) to determine the effects of soil fumigation on soil microorganisms (nematodes and fungi) which may be contributing factors in the yield decline problem, was harvested at 22 months of age. Treatments included a check, and fumigation with Brozone at 200 and 300 pounds per acre, Trizone at 140 and 200 pounds per acre, and DD at 40 gallons per acre. The Brozone and Trizone plots were covered with polyethylene immediately following the injection of the fumigants.

The greatest response in cane growth was obtained from the plots treated with Brozone and Trizone, although there were no significant differences in the yields of tons pol or cane per acre for the different fumigants. The results indicate that increased yields of 32-8560 from soil fumigation treatments were mainly due to the control of nematodes pathogenic to this variety since DD is of limited value as a fungicide at the dosage used. The response from fumigation versus no fumigation is shown in Table 15.

TABLE 15. *Fumigation vs. no fumigation.*

TREATMENT	N	TCA	P.R.	TPA
NO FUMIGATION	3	66.0	7.0	9.4
FUMIGATION	15	78.3	6.9	11.3
HSD		4.0		.6

EXPERIMENTAL STATISTICS

new computer installed

Capabilities in data processing were greatly increased when the IBM 1620 Data Processing System was installed in December 1960. The change-over from the IBM 610 Automatic Decimal Point Computer to the 1620 DPS was not made as smoothly as it might have been. Part of this was brought about by the fact that the 1620 DPS did not become truly operational until late February; two intermittent errors, finally eliminated, caused this excessive delay. The other aspect which slowed the conversion was the profound shift in programming concepts necessitated by changing from an externally stored to an internally stored program system.

The major effort of the department was getting the data-processing system to a point where it could meet some of the more pressing demands. These demands are currently in the areas of plot computations and their statistical analyses; inflow-outflow irrigation studies; overhead sprinkler studies; and a series of multiple regression problems.

Downtime of equipment has averaged less than half an hour per week during recent months. To date the computer has not been detected in an arithmetic error; all errors reported have been traced to humans, either in the computing center or back to laboratory and field personnel who first recorded the data on paper.

system simplifies data processing

Plot computations serve as an example of the sophistication now possible in programming. Basically the raw data consists of plot measurements, cane weights, and various quality measurements on pol ratio samples; however, due to different practices and equipment utilized on the various islands, the variations are rather numerous. Plot area information includes nine variations in the basic ingredients: single to four pol ratio samples on a plot; cane weights derived with or without tare weights; tare weights on one or more trucks; replicated plots of the same treatment, and so on. The number of combinations encountered to date is in the order of twenty different cases to be handled. All of these, and more, are handled by one program requiring only a 6-digit control statement as a preliminary to processing a particular data set. From this statement the computer builds itself a pathway through the instruction maze to get the job done. The output from this program takes two forms -- one a typed record of the plot-by-plot story, and the other a punched paper-tape version of the same thing. The tape is the input data to a companion program which, in turn, performs a statistical analysis on selected characters and prepares a supplemental typed record. In contrast to the one program needed with the 1620 DPS, twelve to fifteen programs for the 610 were needed to accomplish the same work.

FACTORY

processing cush-cush with press

The French screw press from the diffusion investigation was used to evaluate the processing of cush-cush in a cooperative project at the Paia factory of HC&S (Figure 24). Cush-cush return constitutes an added load of close to 10 per cent on the average mill. Separate processing should mean this additional capacity.

Various internal arrangements of the press were used as well as variations in speed and through-put. Tests were made both with and without added maceration.

With the most satisfactory arrangement the capacity of the 10 1/4-inch diameter press averaged 2.3 tons fiber per hour. In tests on cush-cush from the first two mills together with cush-cush and juice from the last mill, discharged bagasse averaged 3.3 per cent pol, 43.0 per cent moisture, and 51.9 per cent fiber. Purity of juice remaining in the bagasse was 58.4. Pol extraction averaged 90.8. Power requirement was 91 hp per ton fiber per hour.

These results make the application of the press appear promising although the horsepower requirements are relatively high.

four gamma ray instruments now weighing bagasse

Gamma radiation bagasse weighers are now in operation at Lihue, Kohala, and Puna. Lihue has an instrument on each tandem. These installations were designed and assembled by the Experiment Station and have been put in for routine control purposes. At the time of final calibration, the instruments had an accuracy of ± 1 per cent on one hour's accumulated weight. The devices may be checked periodically for static accuracy by means of a set of lead filters. Routine calibration, as with any measuring device, is also recommended.

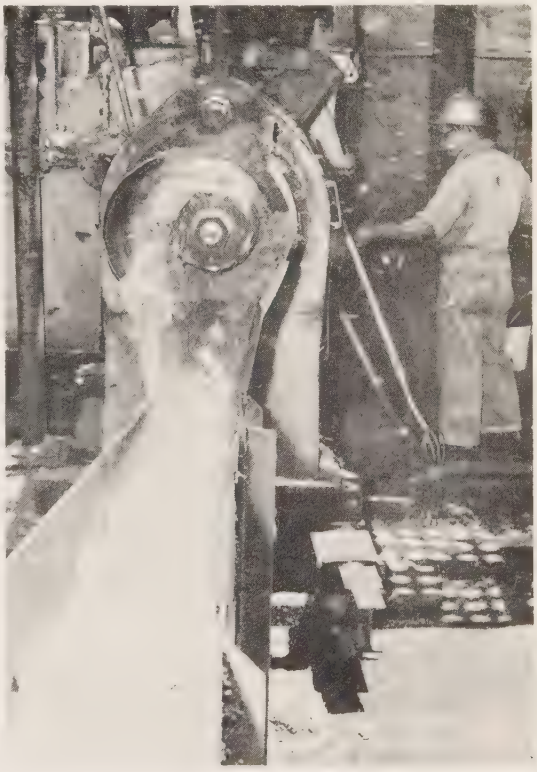


FIGURE 24. *Bagasse discharging from the screw press.*

control instrument to be tried at pilot plant

An instrument has been developed for detecting the limiting current levels on the pilot plant electric membrane demineralizer at Puunene. With this unit,

which is semi-automatic in principle, the operator will be able to determine maximum safe stack current levels and thus run the plant at maximum efficiency without harming the membranes. It is believed that if this instrument is successful the membrane life can be extended to a point where the economics of the process are attractive. Operation of the pilot plant will be resumed again in 1962.

cutting down formation of scale

Laboratory tests on Kahuku juice, which generally has high evaporator scaling characteristics, showed that the magnesium-oxide-clarified juice was less scale-forming than lime-clarified juice. In three out of five tests, the magnesia-treated juice gave essentially no scale. In the tests where scale was formed, it was soft and easily removable.

Magnesium-oxide clarification gave much higher turbidity in clarified juice than lime. Purity increase was likewise lower in the case of magnesia.

testing slag for clarifying

Preliminary tests showed that Tennessee Valley Authority by-product slag in powdered form was ineffective as a clarification agent for mixed juice. Juice treatment in bed-type percolation using granular slag proved effective provided the flow was upward in order to prevent plugging. Purity increase was comparable to that obtained with lime clarification. Clarity was very good due to the filtering action of the bed.

Test work is continuing in order to establish the effective life of the slag so that an economic evaluation of the treatment can be made.

tagging with tritium unsuccessful

Radioassay, using tritium as a tracer, was proposed to determine the amount of water included during crystallization of sucrose. Dow Chemical Company furnished a sample of tritium water and four crystallization tests were conducted using pure sucrose solutions. The crystals were then sent to Dow radiation laboratory for assay.

Results indicated an impossibly high per cent of water (up to 25 per cent). Undoubtedly the tritium had exchanged with the hydrogen in the hydroxyl groups of the sucrose, giving tritium sucrose. The calculations suggest that all of the hydroxyl groups in the sucrose are involved in the equilibrium.

color and moisture in crystals

The quantitative relationship between the color and internal moisture was established for samples of commercial sugar from single strikes. These results, given in Table 16, show more color in the crystal relative to moisture with the larger crystal fractions.

Crystallizations were conducted in the laboratory using factory syrup. Ratios of color to moisture were established for the molasses and the sugar crystal:

Crystallization	Color per Unit Moisture	
	Crystal	Molasses
1	4.5	0.61
2	5.6	0.76

It is evident that the material associated with moisture within the crystal is of different composition than the molasses.

Gel filtration technique, useful in fractionating compounds by molecular weight, was applied to a study of substances within the sugar crystal. The absorption spectrum of four fractions was determined in the ultraviolet region; this technique should prove useful in characterization of the substances.

The 85 per cent methanol-insoluble material in samples of commercial sugar crystal isolated and subfractionated is shown in Table 17. The data show that both the water-insoluble and water-soluble fractions of the methanol-insoluble matter have a retarding effect on filterability. In some cases the one and in some cases the other appears to be governing.

That the effect is substantial was demonstrated in one test where 0.3 per cent of the methanol-insoluble matter was added to a granulated sugar solution. Filterability of this by the Elliott method was 63, compared to 104 for the original.

high-speed centrifuge checks crystal color

A new ultracentrifuge, spinning at 40,000 rpm and giving an average force of 100,000 times gravity, was used to separate finely dispersed and colloidal material from solutions of sugar crystal from all factories. Crystal color was determined before and after ultracentrifuging.

The average crystal color from Oahu, Kauai, and Maui was 0.2 lower after spinning. The average for Hawaii was 0.4 lower. These results suggest that the material thus removed is a more important contribution to crystal color on the "Big Island" than elsewhere. It is probable that this material is deleterious to filterability also.

new method tests filterability

A pressure method for evaluating the filterability of sugars has been developed by the C&H technical staff. This procedure has been investigated during the year and appears to offer a useful standard method.

It has favor in that filtration under pressure more closely simulates refinery practice. The test is made on the crystal rather than whole sugar, which also is closer to refinery operation. It also has the advantage that the quantity of sugar required to make the analysis is much less than that required by the Elliott method.

Indications are that the pressure method can be recommended for adoption as standard for 1962.

TABLE 16. *Color: internal moisture relationship in commercial crystals.*

Factory	Screen Size (Mesh)	Total Moisture %	External Moisture %	Internal Moisture %	Color Absorbancy 50 Ref.Sol.	Color Absorbancy Int.Moist.
Pepeekeo	On 16	0.085	0.019	0.066	0.25	3.8
	Through 16 on 20	0.079	0.014	0.065	0.23	3.5
	Through 20 on 28	0.073	0.009	0.064	0.18	2.8
Lihue	On 16	0.091	0.027	0.064	0.56	8.7
	Through 28 on 35	0.086	0.024	0.062	0.50	8.1
Ookala	Through 14 on 16	0.114	0.032	0.082	0.88	10.7
	Through 28 on 35	0.111	0.025	0.086	0.86	10.0
Pioneer	Through 14 on 16	0.102	0.032	0.070	0.55	7.9
	Through 28 on 35	0.102	0.029	0.073	0.52	7.1

TABLE 17. *Methanol insoluble analysis of sugar crystal.*

Sample	85% Meth. Insoluble %	Press. Filber-Ability ml.	85% Methanol Insoluble: Water Insol. %	85% Methanol Insoluble: Water Soluble %	Water Soluble: I 60% Ethan. Insoluble %	Water Soluble: II 73% Ethan. Insoluble %	Water Soluble: III Above 73% Ethan. Solub. %
Lihue	0.21	184	0.0254	0.1846	0.1334	0.0105	0.0407
Papaaloa	0.15	153	0.0267	0.1233	0.0443	0.0075	0.0715
Waialua	0.09	283	0.0151	0.0749	0.0644	0.0009	0.0096
Wailuku	0.20	137	0.0927	0.1073	0.0692	0.0100	0.0281
Pepeekeo	0.11	226	0.0344	0.0756	0.0555	0.0011	0.0190

INSECT AND RAT CONTROL

new arrival is potential pest

No event of outstanding importance was noted in the field of entomology during the year. New insects continued to enter the state at about the usual rate of 10 to 20 per annum, but only one of these could conceivably become a pest of sugar cane. This is a bill bug, *Calendra venatus vestita* (Chittenden), with a wide range of distribution in the southeast United States and the West Indies, where the larvae are recorded from various hosts. In Hawaii, adults of the species were first found at Hickam Field late in 1960, and by April 1961 both larvae and adults had been found widespread over Oahu. So far, *C. v. vestita* is known here only as a pest of Zoysia lawns, but some of the most serious infestations have been found immediate to cane fields and it is conceivable that the larvae might eventually learn to feed on sugar cane roots.

plantation calls

Plantation calls were fewer than usual and referred, with one exception, to the sugar cane beetle borer, to cane aphids, or to mosquitoes. The exception was a call from Paauhau Sugar Company regarding an unusually severe infestation of a newly planted field by the greasy cutworm, *Agrotis ipsilon* (Hufnagel). The infestation occurred over 74 acres at an elevation of nearly 2,000 feet, and in several areas as many as 80 to 90 per cent of the eyes and young shoots were destroyed, necessitating complete replanting of the field.

beetle borer and its parasite studied

The beetle borer, *Rhabdoscelus obscurus* (Boisduval), continues to be our only insect pest of economic significance, its abundance and consequent importance varying with the effect of variety, crop age, and weather factors upon the life of the borer itself and the efficiency of its parasite, the tachinid fly *Microceromasia sphenophori* (Villeneuve). An indication of the variability in abundance of the pest and the parasite is provided by the results of a brief survey conducted by the Station at Lihue during October 1960. The results showed that 43 per cent of the larvae and pupae of the beetle borer were parasitized -- results not far different from those of a more comprehensive study conducted by the Station 35 years ago.

work done on biology of mealybugs

Mealybugs are under good biological control in Hawaiian cane fields and never attain great abundance. They are considered of negligible importance from the standpoint of direct losses due to their feeding; however, as they are of tropicopolitan distribution and seldom entirely absent from any cane field, either in Hawaii or elsewhere, they are suspected vectors of disease and possible factors in yield decline of cane varieties. The Station has laid a sound foundation for future studies with careful reappraisal of the biology of the pink sugar cane mealybug, *Saccaricoccus sacchari* (Cockerell). This work was

considered necessary because of discrepancies which appeared between observed facts of the insect's biology in Hawaii and published accounts based on work done in the Philippines. Clarification of these discrepancies has required development of new techniques for the rearing of individual mealybugs isolated from the massed populations in which they normally live (Figure 25).

A detailed account of this work, which lasted most of the year, is completed and ready for publication.

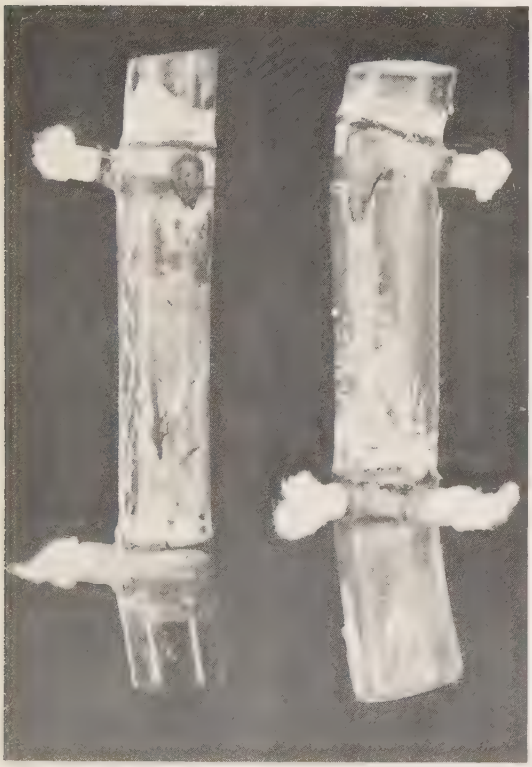


FIGURE 25. Cane sections with mealybug rearing chambers attached.

Investigations on the possible transmission of cane diseases by the pink mealybug have begun with a test involving ratoon stunting disease. Mealybug colonies were developed for this purpose in glass jars, on pieces of cane (variety 45-2120) which exhibited unmistakable RSD symptoms. Adults from the presumably infected colonies were then allowed to settle and feed for eight days on disease-free seedpieces. The seedpieces were then planted in pots side by side with an equal number of check pots planted at the same time with other pieces of cane which had been cut from the original stalks and had been kept free of mealybugs. The test was planted in May and showed no signs of RSD as of the end of September; the pots will continue under observation.

using radiation to track insects

In preparation for future research on insect-transmitted diseases, an experiment was conducted to determine the feasibility of tagging sugar cane aphids, *Aphis sacchari* Zehntner, and sugar cane leafhoppers, *Perkinsiella saccharicida* Kirkaldy, with the radioactive isotope P32. It was found quite practical to tag both species by allowing field-collected insects to feed on the tops of sugar cane stalks with the cut end immersed in a nutrient solution containing the isotope. In the case of the aphids, a solution of 2.85 millicuries per milliliter resulted in many individuals with a substantial radiation count after a feeding period of only 24 hours. With the feeding period extended to 96 hours, demonstrable radiation lasted at least 10 days after the aphids were removed to normal phosphorus-free leaves.

Tests with sugar cane leafhoppers showed that adults, particularly the females, acquired detectable radiation in one day of feeding on cane tops immersed in a nutrient solution with less than one-half the calculated radioactivity of the solution used with aphids. The data obtained in these tests indicated that the male leafhoppers acquire less radioactivity than the females in a given period of time; and also that activity acquired during the nymphal stages lasts into the adult stage.

rat control program

There has been considerably less demand this year for the services of the Department in the field of rat control than any year since 1956. Two reasons are adduced to explain this:

1. Rat populations, particularly those of the Norway rat, appear to have fluctuated towards a period of natural scarcity on most plantations.

2. Plantations where rats had been most abundant in the past are the ones where the largest and most effective abatement programs have been developed and where, consequently, the thinnest populations are bound to appear today.

Evaluating baits:

Laboratory testing of new baits and carriers has continued, in the hope that one could be found with clear advantages over the Warfarin-rolled oats in general use. Two commercial pelletized Warfarin baits have shown performances comparable to Warfarin-rolled oats, but no commercial bait has been found with enough promise to warrant the large-scale plantation trials which its incorportation into regular control routines would demand.

A general weakness of all commercially prepared baits is their cost, which is never sufficiently low to induce the plantations to consider switching to their use, regardless of special advantages which they may possess. Cost has become the main consideration in this respect on all plantations and no new bait will stand much chance of acceptance--regardless of quality--until one very much cheaper than rolled oats is found. For this reason, a close study has been undertaken of the possibilities of macadamia nut waste. If the macadamia industry continues to grow at the present rate, this side product of the processing plants should soon be available in large quantity, presumably at a cost significantly lower than rolled oats imported from the Mainland.

It appears so far that macadamia is generally better accepted by rats than rolled oats and that it is not difficult to treat the new material. The most efficient way to make the completed baits on a commercial scale remains to be worked out in practice, however, and so do the economics of their use on plantation scale. Honokaa Sugar Company is the only plantation using the material exclusively so far. Unfortunately, since Honokaa has presently only a relatively minor rat problem and, at the same time, a much larger supply of macadamia waste than the problem requires, the work on this plantation is unlikely to provide answers to all the questions which might arise in connection with the use of the material elsewhere.

Bait-dispensing stations:

Interest in the use of permanent stations has continued to grow during the year, and several new experimental models have been given to the plantations for trial by the manufacturers. None of the models, so far, has shown itself superior -- in our judgment -- to the Inverted Tee dispenser devised by the Entomology Department last year. This model itself, however, is not being tested on any plantation in a manner designed to bring out all the potential advantages of its use. So far, 100 of the Inverted Tees are in use at Oahu Sugar Company, 200 at Waialua Agricultural Company, and 200 at Lihue Plantation Company.

All of these dispensers were provided by the Station, and in the course of their manufacture the technique of making them has been perfected. Figure 26 illustrates the templates with which the components are shaped and with which a unit can be made in a few minutes. It is estimated that with similar techniques the per-unit cost of manufacturing these dispensers on a plantation should not be higher than 60 or 70 cents.

FIGURE 26. *Templates for construction of HSPA Tee bait dispensers.*

Rat behavior to be studied:

Dr. John B. Calhoun of the National Institute of Mental Health, an eminent authority on animal behavior and small mammal ecology, has demonstrated the feasibility of inducing small mammals to migrate en masse in a predetermined direction. He visited the Station in September to suggest the possibility of using mass migration as a means of rat control. The staff spent several days with Dr. Calhoun on Kauai and Hawaii searching for a suitable site in which to conduct preliminary experiments. One suitable site was found on the Hamakua Coast and it is planned to proceed with the project in 1961 either at this site or another which may be chosen later. The work will be conducted according to a plan formulated by Dr. Calhoun, but under the direct responsibility of the Entomology Department.

IRRIGATION

furrow irrigation studies

Water distribution tests have demonstrated that proper adjustment in furrow inflow rate and irrigation time improved the uniformity of application and reduced runoff. The test was conducted in a continuous long-line irrigation system (aluminum flume) in Field 18 at Oahu Sugar Company. Table 18 illustrates the relative influence of inflow rates, age of crop, and time of irrigation.

At cane age of two months, an inflow rate of 28 gpm for a 64-minute period produced 1.20 inches of runoff. In the next irrigation, a flow of 14 gpm for 90 minutes produced a higher net application, a good water distribution, and 0.31 inch of runoff.

At cane age of eight months, a 19-gpm flow for 107 minutes produced a good water distribution with 0.5 inch of runoff. At age 13 months (round 22), a flow of 27 gpm for 139 minutes resulted in a poor water distribution and excessive application of water. In the next irrigation (round 23), the flow rate was increased to 37 gpm for a period of 79 minutes, giving a reduction in application and a more uniform distribution.

Furrow infiltration rate increased with successive irrigations at various ages of cane (Table 18). Infiltration rate was also influenced by irrigation time and inflow rate; hence, an equation was derived as follows:

$$I_r = 0.419 + 0.041\,F + 0.063\,A + 0.001\,I_t$$

where A = age in months, F = inflow rate in gpm, I_t = infiltration time in minutes, and I_r = furrow infiltration rate in inches per hour. The correlation between observed and computed values was 0.94.

This equation could be used to compute length of furrow at maximum age. For example: let A = 20 months, I_t = 90 and F = 40, the maximum workable discharge from an outlet. Then I_r = 3.37 inches per hour, or .193 gpm per running foot of furrow on a 5.5-foot spacing. Length = $\frac{40}{.193}$ = 207 feet maximum desired length of furrow. If a longer length is used, more water would be required for irrigation, giving a lower irrigation efficiency.

overhead irrigation methods evaluated

The Industrial Engineering Department has made a study of overhead irrigation methods. The analysis points up that plantation conditions will dictate whether or not sprinkler irrigation will be profitable and will also dictate the method of everhead irrigation. Conditions having major economic influence are:

1. Total water requirement for evapotranspiration
2. Useful rainfall.
3. Soil moisture storage capacity
4. Amount of irrigation water available and when available
5. Cost of irrigation water
6. Whether there are cane areas presently in deficit and, if so, how many and the extent of the deficit
7. Whether there is new land available for cane production if irrigation water were available.

TABLE 18. *Irrigation data in relation to irrigation rounds and age of crop*

Irrigation Round	Age mo.	Inflow Rate gpm	Irrig. Time min.	Gross Appl. Furrow in.	Net Appl. 0–100 ft. in.	Net Appl. 100–200 ft. in.	Over-flow in.	Furrow Infil. Rate in./hr
4	2	28	64	2.81	1.34	1.48	1.20	1.19
5	2	14	90	1.82	1.56	1.46	0.31	1.01
15	8	19	107	3.26	3.02	2.61	0.51	1.57
22	13	27	139	5.56	5.27	4.01	0.92	2.29
23	14	37	79	4.20	3.81	3.42	0.59	2.89
27	17	36	96	5.05	4.56	3.91	0.70	2.85

pumping from lateral ditch-roadways shows potential

The methods study further shows that a unitized sprinkler (engine, pump, suction equipment, and sprinkler mounted on a skip or wheels) pumping from lateral ditch-roadways may be competitive with surface irrigation under certain conditions. The chief advantage of this method is the relatively low initial capital cost. To apply this method to slope fields will require solution of several problems:

1. **Field Layout:** Layouts from contour maps indicate that most fields can be installed to lateral ditch-roadways by using flume or tube to drop to a lower level and by reducing, as necessary, the distance between lateral sets. Two problems exist in this area, developing layout techniques and developing the best material and method of dropping a lateral to a lower level.

2. **Lateral ditch-roadways.** Problems here are construction, provisions for irrigation water runoff and storm control, pumping from the ditch with minimum water loss, minimizing seepage losses, soil stabilization, and mechanization of repair and maintenance.

3. **Metering water to ditches.** Water must be metered from the concrete flume to the lateral ditches at a low capital cost. To minimize water losses, metering to ditches must be accurate or provisions must be made to regulate the pumping unit to handle the water delivered.

4. **Pumping unit assembly.** The unitized pumping unit should be designed so that it can be moved readily from one set to another without a lot of handwork and delays. Construction must be rugged and sprinkler vibration must be controlled. The engine should be operated continuously. Fuel capacities should be for at least 24 hours of operation. A portable ditch pani or sump with compatible suction equipment needs to be developed.

5. **Moving equipment.** It may be necessary to develop special handling equipment.

6. **Other.** A minor problem is the servicing of the pumping units. Regular garage service trucks cannot readily be used. One possibility is to have a fuel storage tank with pump and a lubricating oil storage tank mounted on a skip which can be taken infield by the sprinkler moving machine. The garage service truck would service the skip and the irrigator would service the pumping unit. Such a service unit needs to be designed.

The Field Engineering Department is solving these problems.

long-barrel sprinkler could provide advantages

The analyses brought out the importance of "throw" (radius, or acres per set). Figure 27 shows the relationship between costs and discharge rates, acres per set (or "throw"), and application rates when pumping from lateral ditch-roadways.

1. Costs rise sharply as discharge rates per sprinkler decrease below approximately 700 gpm.

2. Once discharge rates exceed approximately 700 gpm, there is little to be gained from higher discharge rates per se.

3. Acres per set is an important cost factor. The higher the discharge rates,

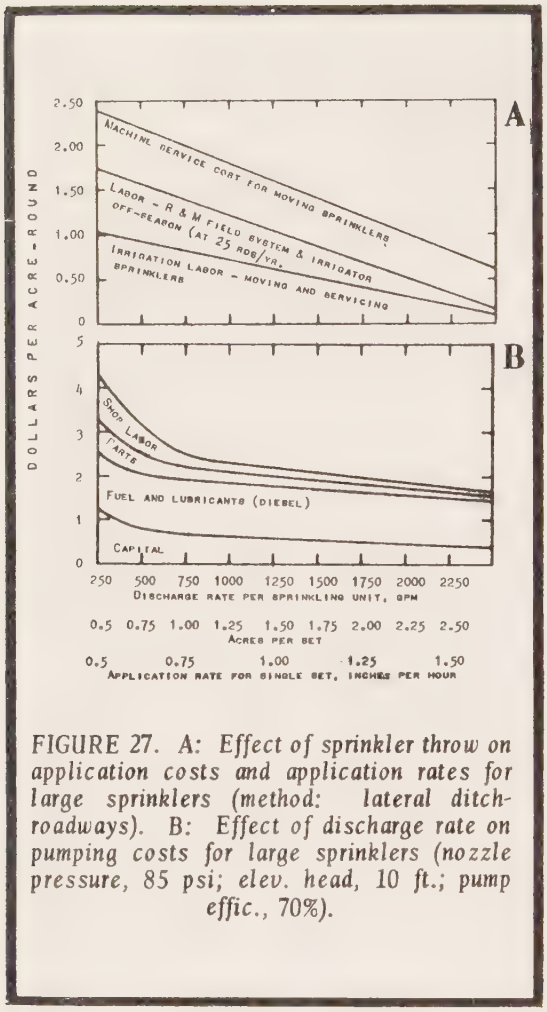


FIGURE 27. A: Effect of sprinkler throw on application costs and application rates for large sprinklers (method: lateral ditch-roadways). B: Effect of discharge rate on pumping costs for large sprinklers (nozzle pressure, 85 psi; elev. head, 10 ft.; pump effic., 70%).

the greater the "throw" -- with accompanying increases in acres per set.

4. The greater the discharge rate, the higher the application rate (inches per hour). Much of the irrigated cane lands cannot sustain application rates on bare soil in excess of 0.4 to 0.5 inch per hour, unless furrows or some other configurations are installed. On slope fields, furrows are not compatible with operation of the harvesters under development.

This cost:application rate dilemma suggests the possibility of physically extending the sprinkling radius with the use of a long-barreled sprinkler. For example, by extending the radius 70 feet for a 550 gpm sprinkler and adding a fill-in sprinkler of 150 gpm, the maximum application rate is reduced from 0.78 to 0.45 inch per hour, while the average set with overlap is increased from approximately 1 to 2 acres and the discharge rate is increased from 550 gpm to 700 gpm. What happens is that the normal "throw" of 175 feet is increased to 245 feet with the wetted acres per set increased from 2.21 acres to 4.33 acres, thus decreasing the application rate. The advantage of such a long-barreled sprinkler would not be confined to a portable sprinkler pumping from lateral ditch roadways. Used with portable pipe, such a sprinkler would reduce pipe-moving in proportion to the increase in distance between lateral pipes. It may even provide a way to reduce capital costs for permanent or semi-permanent systems of closely-spaced small sprinklers. Figure 28 is a sketch illustrating the idea.

water economy shown in 2-year sprinkler test

The 14.5-acre Sequa-Matic test which was installed at HC&S in May 1959 was harvested in May 1961. This experiment was designed to investigate some of the potentials and problems of using a closely spaced semi-permanent sprinkler system in sugar cane.

Crop variety 50-7209 yielded 120.9 tons cane per acre and 16.1 tons sugar per acre on land that had been fallow for a number of years. No check cane area was established under standard surface irrigation practices; however, comparison with a field in the vicinity indicated that the yield was comparable with a saving of 82 inches of water per crop. One significant result of the experiment is that the crop was brought to maturity with 134.5 inches of irrigation water delivered to the field edge plus 5.8 inches of effective rainfall, for a total pre-ripening irrigation of 140.3 inches. The corresponding pan evaporation was 143.0 inches. During ripening there was a total of 14.2 inches of effective rainfall with a corresponding pan evaporation of 41.8 inches. During the test the irrigation interval was determined by means of tensiometers and

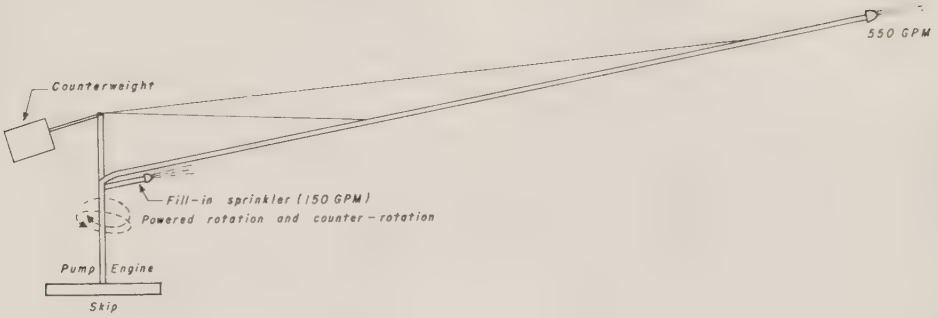


FIGURE 28. Long-barreled sprinkler.

verified with Bouyoucos blocks. Irrigation was started when the moisture tension reached 0.25 atmosphere at the 18-inch depth. Irrigation was stopped when the tension was reduced to 0.10 atmosphere. This technique was possible because of the sequencing nature of the system. For example, eight irrigations, each of 1-hour duration over a 5-day period, would produce a 3-inch total application.

The field was laid out so that the laterals could be laid with the cane lines. One variable introduced was the number of lines skipped where the laterals were laid. In certain sections the laterals were laid between the 5-foot lines and in other sections one, two, and three lines were omitted with the lateral placed in the center of the area. Block tests were harvested in these different sections and no differences in yield were indicated. There was no pushing of cane during the growing of the crop.

Two sprinkler spacings were used, 30 x 50 feet and 30 x 60 feet. Block harvest tests showed 145.2 tons cane per acre and 21.4 tons pol per acre for the 30 x 50 areas and 145.6 tons per acre and 21.6 tons pol per acre for the 30 x 60 areas.

The good yield with water economy can be attributed directly to the uniform distribution of water and to the rate of application, which was below the rate of intake of the soil. Distribution tests covering a series of 22 irrigations showed an 85.8 uniformity coefficient for the 30 x 50 areas. Irrigations were carried out by sequencing across the field at intervals of one hour; thus, an irrigation of 4 inches required ten 0.4-inch passes across the field. The effect of the variable winds in distribution was shown to be favorable.

Part of the fertilizer was applied through the sprinkler system. The maximum concentration used was 0.16 per cent nitrogen or 0.70 per cent urea, and no burning was observed. Flushing the system as the last phase of the irrigation resulted in no detrimental effects to either the equipment or the cane. A check of the distribution showed that 90 per cent of the area received an application of ±24 per cent of the mean.

Minimum riser height should be approximately 14.5 feet. A suitable riser support was found to be a 2 x 2 x 96-inch wooden stake driven into the ground next to the riser, with the riser tied to the stake with a nylon cord. Very clean

or very well-filtered water is required to minimize trouble with trash and silt clogging the small-diameter nozzles of the 7 gpm sprinklers.

Installation costs were about $10 per acre, and the costs of removing equipment varied from $12.10 to $32.25 per acre per crop. The most satisfactory cost was obtained in conjunction with the cut-load harvester operation. The harvester cut and loaded the cane up to the lateral, then the lateral was removed by hand. The possibility of using a flume pickup machine for removal of risers and laterals ahead of burning appeared to be promising. Some of the equipment was removed after firing and was found to be damaged.

sprinklers evaluated on oahu by two methods

Performance of certain high-capacity sprinklers has been evaluated. One method was the standard procedure of testing a single sprinkler with a grid of gauges; tests covered a range of operating and climatic conditions. The Hanawai Target Master 1500 was tested at Oahu Sugar in a series of 23 test patterns. These covered wind conditions ranging from 1.1 mph to 14.5 mph and flow rates varying from approximately 500 to 800 gpm. These tests indicated:

1. An increase in wind velocity can improve uniformity of coverage from a single-nozzle sprinkler.
2. There does not appear to be any consistent trend of improvement as the pressure increases.
3. Counter-rotation in the operation of a sprinkler, as opposed to continuous clockwise rotation, did not materially improve the uniformity of distribution.
4. A 360° sprinkling arc, as opposed to a 270° sprinkling arc, resulted in improved uniformity of application.
5. A fill-in nozzle greatly improved the ability of the sprinkler to provide adequate coverage to large percentages of the field.
6. The sprinkler achieved approximately 71 per cent of the theoretical throw at an operating pressure of 70 psi and 58 per cent at 100 psi.

Results of these test data were used in the layout of a field at Oahu Sugar.

In order to determine the performance of the Target Master 1500 with higher rates of flow and higher wind conditions, 35 tests were run at Kohala. Rate of flow through the single-nozzle sprinkler was varied up to 1,100 gpm and the winds ranged up to 15 mph. This work showed that adequate irrigation can be designed for the Target Master 1500. These data are being cataloged with the Station's computer facilities.

A second method investigated the application and distribution of the Hanawai Target Master 3000 at Ewa Plantation. Rain gauges, distributed in the field by a method of stratified randomization, were read following routine irrigation of the area. Analysis and calculations provided an operating procedure which insured an adequate irrigation of the field. The techniques of this second method proved to be a practical means of determining what is actually happening in the field by integrating the sprinkler performance with the field layout and with routine operations.

leaf tissue may lead to easier sampling for moisture content

Previous work has established the following points about cane joints 4-5:

1. For boom growth their moisture content is 92 ±1 per cent.
2. Their moisture is independent of nitrogen, unlike the 3-6 sheaths and 8-10 joints which are quite sensitive (1956 Ann. Rep. p. 15).
3. By drying off to about 85 per cent on September 14, flowering is inhibited (1957 Ann. Rep. p. 63).
4. The ten varieties studied show not over 1 per cent difference in their 4-5 moisture under normal irrigation at Makiki.
5. The 4-5 joints have a higher moisture content than any other major tissue measured, being even higher than the growing point above.

Recent experimental work has provided evidence to support the following:

1. The 4-5 joints are most sensitive to recently developed moisture stresses.
2. The stresses developed between

extended irrigation rounds are readily measured.

3. Within a given treatment there is a high correlation between the moisture of blade No. 1 and the 4-5 joint moisture.

The response of stalk tissue moisture to moisture tension applied for a short time by adding salt to a culture solution is shown in Figure 29. The low tension curve (0.4 atmosphere is due to normal nutrient salts) shows the moisture gradient along the upper portion of stalks of young cane in boom growth stage when well watered. The No. 10 joint has 11 per cent less moisture than the No. 5. An added 2 atmospheres tension brings about a measurable drop, while 4 atmospheres additional drops the moisture 6 or 7 per cent.

Figure 30 shows that this degree of dehydration is sufficient to almost stop translocation of tagged sugars from leaf No. 8 into those upper tissues. Measurements show that growth (elongation) has practically ceased. This is also the moisture level at which flowering is largely inhibited.

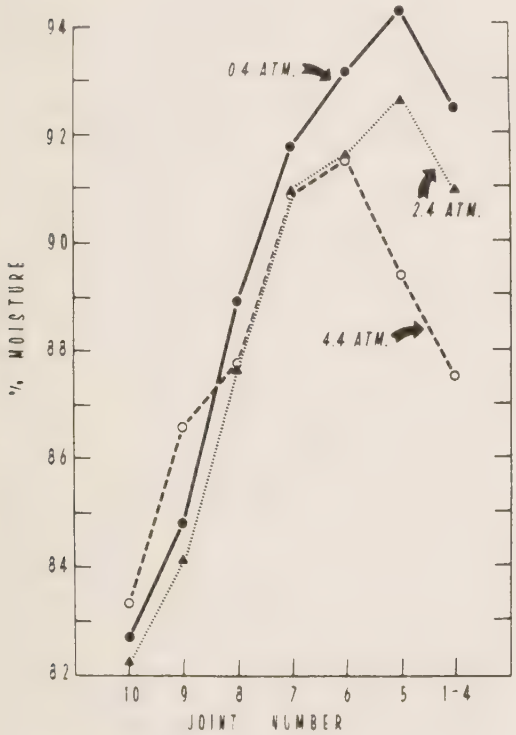


FIGURE 29. *Moisture distribution on sugar cane plants subjected to different osmotic pressures in culture solution.*

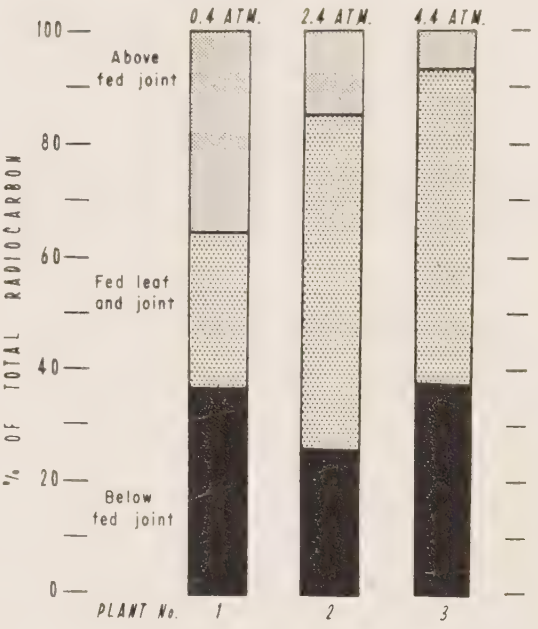


FIGURE 30. *Moisture tension in upper joints reduces upward translocation of sugars. Distribution of C14 24 hours after feeding leaf No. 8 in each of three plants growing in solutions of three different pressures. Additional osmotic material is NaCl.*

The 4-5 joint moisture measurements were recently applied to some plots in the Waipio Irrigation Test. The F treatment, which received adequate irrigation according to pan readings, was compared with the A and D treatments, which received about one-half as many rounds of irrigation. Results are shown in Figure 31. The frequent rounds seem to be adequate, maintaining a moisture of 92 per cent or above most of the time; on the other hand, the effect of delayed irrigations on the A plots is very clear. According to moisture tension curves developed from laboratory studies, the observed drops would result from about 2 atmospheres tension. There would be some slowing of growth and metabolic activity, but possibly not enough to greatly reduce yield.

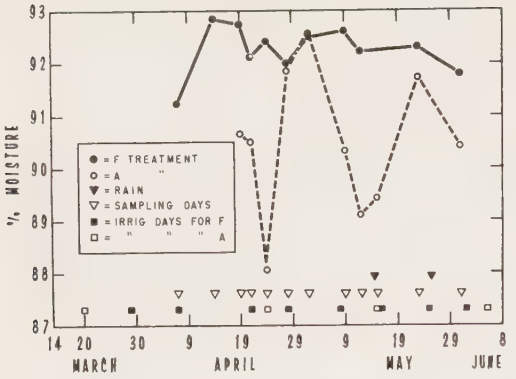


FIGURE 31. *Moisture composition of 4-5 joint tissue. (Waipio Irrigation Test: F treatment - adequate irrigation according to pan readings; A treatments - approximately one-half of F).*

Figure 32 shows the high correlation between the moisture content of the 4-5 joint and blade No. 1. There is considerable scatter when the moisture is fully adequate, but when stress is applied the moistures drop proportionally. Hence, the No. 1 leaf may provide tissue which will serve equally well as an indicator of tension and have the advantage of being more easily sampled than the 4-5 joint.

estimating water needs of crop

Pan evaporation data in the evapotranspiration project at HC&S have been compared with the weather elements according to the Thornthwaite and Penman methods. It was found that the Thornthwaite estimates, which express potential evapotranspiration as a function of the mean monthly air temperature, are only about 54 per cent of the pan evaporation (Figure 33). The Thornthwaite estimates also show a lag of about a month behind pan evaporation.

Penman combines the energy budget and aerodynamic approaches in a formula for estimating evaporation from temperature, wind, humidity, and radiation. His estimates agree well with observed monthly pan evaporation, the correlation coefficient being 0.86 (Figure 33). On the average, the Penman value is 89 per cent of the pan evaporation, with lower values in winter. In the Penman equation, radiation was found to be the most important term, accounting for about 80 per cent of the evaporative process.

Potential evapotranspiration of sugar cane as recorded by lysimeters at HC&S was further compared with pan evaporation. Figure 34 shows the average

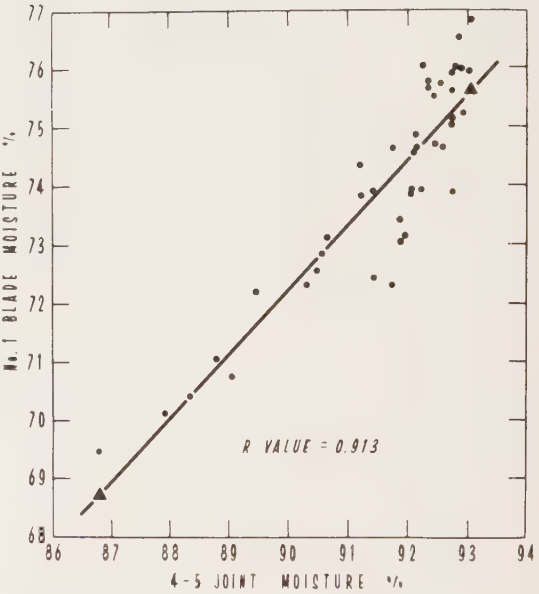


FIGURE 32. *Relationship between moisture compositions of No. 1 blade and 4-5 joint tissue.*

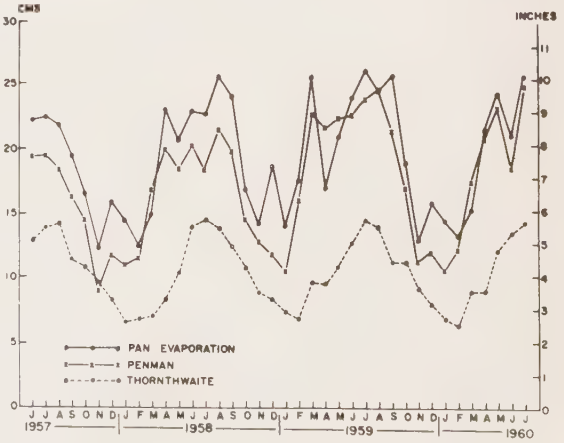


FIGURE 33. *Pan evaporation at Field 906, HC&S, as compared with the Penman and Thornthwaite estimates.*

evapotranspiration/pan evaporation ratios with respect to the cane age for both the planted and ratoon crops for three fields. The ratio increases from 0.40 for young cane to 1.01 when the canopy is fully developed at the age of five months. The ratio reaches a peak of 1.20 when the cane is 10 months old followed by a gradual decrease to 0.98 seven months later, and a subsequent rise before the cane is harvested.

The average cane evapotranspiration/pan evaporation ratio at HC&S is 0.98 for all cane ages and 1.08 for the mature cane after it is four months old. For practical purposes, a convenient ratio of 1 to 1 has been adopted for estimating water needs of the cane crop and the water balance of the plantation areas.

Figure 35 is a monthly water balance chart at Oahu Sugar Company. The difference between the pan evaporation and the median rainfall represents the approximate water need for a sugar cane crop. The water balance chart is therefore in some degree a measure of the agricultural potential of the particular place. Such information is essential for intelligent management of the water resources.

FIGURE 34. *Average evapotranspiration:pan evaporation ratios from three HC&S fields compared to age of cane.*

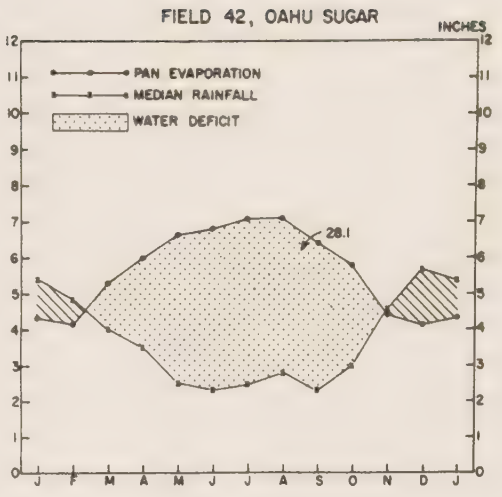


FIGURE 35. *Monthly water balance chart for Field 42, Oahu Sugar Co.*

consumption of water by sugar cane

Work continued on the determination of the ratio of evapotranspiration of the sugar cane plant to evaporation from a free water surface of a standard weather bureau pan. In the determination of this ratio, the following procedure was carried out.

In a plot 60x40 feet, two trenches were dug 20 feet from each end of the plot. These trenches were 8 feet deep and 12 feet long. In each trench a piece of sheet metal 8x12 feet was buried upright to act as a barrier through which neither roots nor water might pass; thus two sections 20 feet long were isolated from the remainder of their respective rows. Gypsum moisture blocks were buried in each of the two isolated rows to a depth of 6 feet and extended laterally for 5 feet. The blocks were spaced 6 inches apart vertically and 1 foot horizontally. The two isolated sections had three buffer rows running parallel to them.

The plot was planted to the variety 37-1933 and as the sugar cane grew the two isolated sections became an integral part of the plot, surrounded on all sides with plants similar to the plants in the two sections in question.

All irrigation water was metered and an even distribution of water was assured by use of 1-inch polyethylene pipe, which lay in the bottom of the furrows. This pipe had distributing holes spaced 1 foot apart.

At each irrigation, care was taken to apply just enough water to replenish the soil reservoir in the upper volume of soil and thus prevent loss by deep seepage below the root zone. In this way, all water applied could be accounted for and the only means for its removal from the soil was by evapotranspiration.

From October 17 to November 27 the plot received a total of 6.72 inches of water; during this same period a total of 7.64 inches were evaporated from a standard pan. During a second period, from May 29 to August 22, the plot received a total of 17.32 inches and the evaporation from a standard pan for the same period was 18.89 inches. The ratio $\frac{ET}{EP}$ for the two periods of times was .88 and .92, respectively, the average being .90.

overhead vs furrow irrigation

The MASI I surface-overhead irrigation experiment, started in September 1958, was harvested 24 months later in September 1960. A formal report on the complete experiment is currently being prepared for publication. The following conclusions were obtained:

1. The total net water applied by irrigation and useful rain to separate plots ranged between 123 to 160 inches. Within this range of net water applied, 15 acre inches produced one ton of sugar.

2. No significant difference was found in yield between trash-covered (10 tons per acre dry material) and bare soil plots; however, less water was applied to the trash-covered plots than to the bare plots early in the crop.

3. When the yields for the two irrigation methods were compared after taking the regression of yield on water into account, there was no significant difference between irrigation methods, although furrow-irrigated yields were greater than overhead-irrigated yields.

Surface configuration was different for the two irrigation methods. Surface-irrigated plots were deeply furrowed and the overhead plots were nearly flat. This experiment was not designed to evaluate separately the effect of configuration between methods because type of configuration would, in practice, be dictated by the irrigation method.

4. The infiltration rate of initially bare, but planted, plots increased from 0.4 inch per hour to 1.5 inches per hour over a period of 17 months during the crop cycle. Trash-covered plots absorbed water at rates greater than 2.0 inches per hour. (Figure 36 shows the change in infiltration rate in relation to age of crop.)

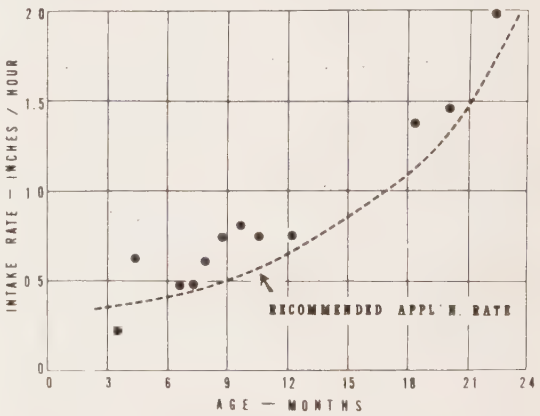


FIGURE 36. *Infiltration rate in relation to age of crop. Bare surface treatment, slope 0.5%.*

The interaction of water and fertilization and the effect of water on yield were the two most important relationships studied in the MASI I experiment. Surface configuration within irrigation methods, method of irrigation, and surface cover gave non-significant yield results. However, surface configuration, surface cover, and method of irrigation all have very important implications in relation to the cost of field operations and water management techniques.

Another MASI experiment was planted in Field 4B at HC&S in May 1961 to amplify some of the more important results of the previous experiment. The new experiment includes the following objectives:

1. Comparison of overhead-irrigated with surface-irrigated cane for similar levels of applied water and surface configuration.

2. A study of sugar yield in relation to amount and frequency of irrigation during imposed drought. The length and intensity of drought have been based upon the historical ditch flow from mountain water sources.

3. A study of sugar yield based on a water priority system with a crop cycle. This objective is designed to provide information which could be used to determine the most desirable age of cane to apply irrigation water, thus establishing water conservation procedures to be employed during drought periods. In the new experiment, soil samples and crop log samples will be taken to study fertilization - irrigation interaction under these drought conditions.

infiltration rates and overhead irrigation

During the past year, infiltration rate studies were completed on two soil types at Oahu Sugar and three soils at Kahuku. These studies were made with a fixed rotating sprinkler infiltrometer, which is easily disassembled, transported, and reassembled at predetermined test sites. This type of equipment sprays water through a range of application rates over small plots, making it possible to determine infiltration rates associated with runoffs ranging from none to high amounts in the same irrigation. In a typical test, when the application rate was 1.38 inches per hour, the resulting intake rate after 150 minutes of irrigation was about 0.8 inch per hour. This is in contrast to an intake rate of 0.65 inch per hour, corresponding to an application rate of 0.85 inch per hour. Where the application rate was 0.5 inch per hour, runoff was still observed. This variation in intake rate is related to the time opportunity for infiltration, or specifically the number of drops that hit a unit surface area per unit of time. In other words, the higher the drop frequency on the soil surface, the higher the intake rate. This is an important phenomenon when high-application-rate sprinklers are being considered for use in overhead irrigation on irregular soil sloping surfaces.

surface runoff control needed with some sprinklers

Soil infiltration rate values were compared with application rate values for Target Master 1500 sprinklers equipped with 1 5/8-inch and 1/2-inch nozzles to determine the percentage of the pattern area over which water was applied at rates greater than the soil intake rate. This comparison demonstrated that 40 per cent of the pattern area received water at a rate greater than 0.7 inch per hour; hence runoff would be expected to occur during irrigation of this soil with the Target Master 1500. Therefore, a study was made of the effect of surface runoff on water distribution and runoff from field-scale size blocks. A typical result is presented in Table 19 to show sources of maldistribution and the excess water that should be applied to compensate for these distribution losses of water corresponding to various levels of irrigation adequacy.

These data can be interpreted as follows: to irrigate at adequacy of 70 per cent (70 per cent of field to receive an adequate amount of water), then the required gross application would be 1.15 inches of water for every inch of water desired on a net basis. If adequacy of 90 per cent is desired, then gross application would be 1.65 inches for every inch required.

In tests completed between the 3rd and 17th irrigation rounds, surface redistribution during irrigation did not improve over-all water distribution. In fact, field distribution was poorer than the overlap pattern distribution of sprinklers alone in most of the tests. When high-application-rate sprinklers are used for irrigation, some type of surface configuration is desirable to control runoff and soil erosion.

TABLE 19. *Per cent of distribution losses related to irrigation adequacy*

Source of Maldistribution	Irrigation Adequacy* 70	80	90
Sprinkler	4	14	22
Soil surface	10	16	42
Runoff	1	1	1
Total	15	31	65
Gross application requirement - in inches	1.15	1.31	1.65

**Percent of field to receive adequate amount of water*

split application best for fertilizing via irrigation water

It is a common practice to apply soluble fertilizer materials in irrigation water by splitting the application into three or more increments. A study of furrow water and nitrogen distribution, recently completed in Field 18, Oahu Sugar Company, yielded data for comparing the uniformity of a single application vs. split applications.

Two curves presented in Figure 37 show the range in amounts of N for single vs. split application. The split application is much more uniform than the single application. This result can be explained on the basis of mechanical conditions associated with dispensing the aqua ammonia in the irrigation and its subsequent distribution in the furrow during irrigation.

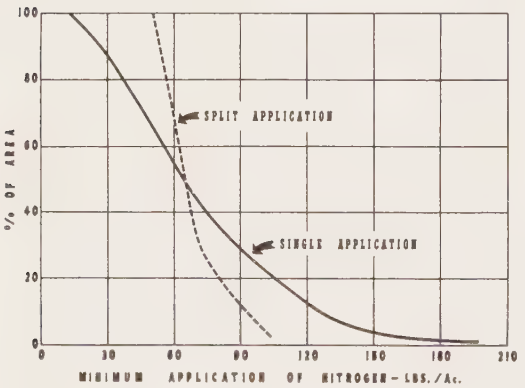


FIGURE 37. *Single vs. split application of aqua ammonia in irrigation water.*

shape and slope of furrow influence irrigation

The effect of furrow shape and furrow slope on the gross furrow irrigation requirement and yield was studied at Waipio Substation of the Experiment Station.

Table 20 shows that the average depth of water applied per irrigation round was greater for "U"-shape furrows than for "V"-shape furrows. In this experiment, the effect of slope was greater than the effect of furrow shape. The 2 per cent slope plots averaged 0.79 inch less water per irrigation than the 1 per cent plots, whereas the difference between "U" and "V" shape was only 0.35 inch per irrigation round.

Table 21 gives the average plot yields corresponding to slope and shape. These results show no statistically significant differences in yield, although a trend toward lower yield in the "V"-shape and 2 per cent slope appears evident. This difference of 1.1 TPA is associated with a corresponding difference of 31 inches of water between "V" - shape 1 per cent and "V"-shape 2 per cent treatments.

TABLE 20. *Relation of applied water to furrow shape and slope (inches)*

	Slope 1%	2%
"U"-Shape	3.09	2.61
"V"-Shape	2.95	2.05

TABLE 21. *Relation of applied water to slope to TPA.*

	Slope 1%	2%
"U"-Shape	19.9	19.7
"V"-Shape	20.1	19.0

how much water will soil hold?

Preliminary data from fields of Makaweli silty clay loam at Olokele Sugar Company show that the bulk densities of the upper 18 inches of plowed soil increased for the first six months after plowing. At the end of the six-month period, the bulk densities were very similar to those found in soils which support a ratoon (Figure 38). The bulk densities were taken in four replications at each of two locations in plant Field 230 and at a single location in ratoon Field 130. At one location in Field 230, the bulk density changed from 1.14 at two months to 1.23 at six months, an increase of 8 per cent. It is of interest that 36 per cent moisture by weight of the lower density would contain the same of water as 33 per cent moisture by weight at the higher density.

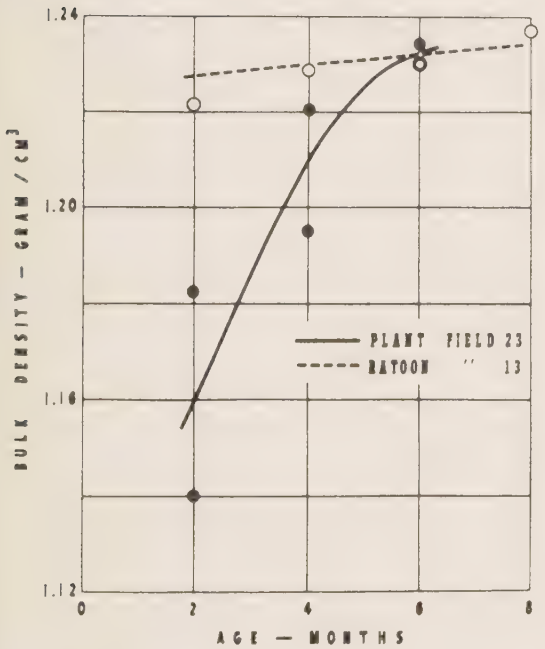


FIGURE 38. *Bulk densities in two fields at Olokele (Makaweli silty clay loam).*

leak-resistant gate cuts water losses

In cooperation with the Wailuku Sugar Company, a highly leak-resistant gate for supply ditches has been developed to eliminate all loss which originally passed through the space between the gate and its retainer or guide. The sealing surface is parallel to the direction of water flow rather than perpendicular, resulting in an effective water seal with moderate closing forces. A closed cellular neoprene rod, 9/16-inch in diameter, is held in a retaining groove in the gate; as the gate is pushed into place, the neoprene rod forms a seal between the smooth surface of the retainer and the groove in the gate. Gate kits are available from a Honolulu supplier for 24-inch and 30-inch gates.

machine installs spile

A machine for installing spile has been designed to be mounted on a 40 hp tractor on which the right-hand track assembly had been moved out 30 inches to provide a 72-inch gauge.

The equipment consists of a bin for storage of the spiles and a two-piece hydraulic blade which penetrates the ditch bank to the proper depth, then separates to allow the spile to drop to the bottom of the formed notch. As the blade is lifted the soil caves from each side and covers the spile. A small quantity of soil added by hand to completely fill the notch in the ditch bank. By lifting the blade the full height, a spile drops out of the bin into a receiver on the top edge of the blade. When the two plates separate after penetration of the bank the tube drops to the bottom of the soil notch (Figures 39 and 40).

This machine has been operated most extensively at Lihue and Kahuku. Results at Lihue showed that an operator with a helper accomplished as much as a crew of 6 to 8 men; 600 to 700 spiles were installed per 8-hour shift.

Future development plans call for: (a) improved driver visibility; (b) faster acting hydraulics; (c) prevention of jamming of the spiles in the storage bin; (d) added weight at the right rear of the tractor to avoid raising as the blade penetrates the ditch bank; and (e) added storage and dispensing facilities on the machine for the spile gates.

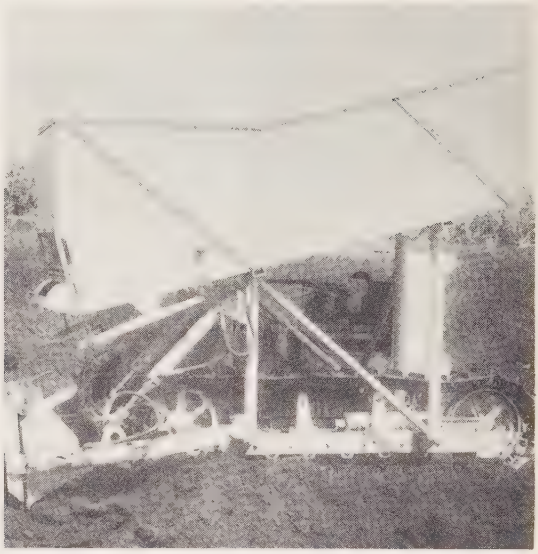


FIGURE 39. *Spile-installing machine making the notch and dropping the spile into place.*

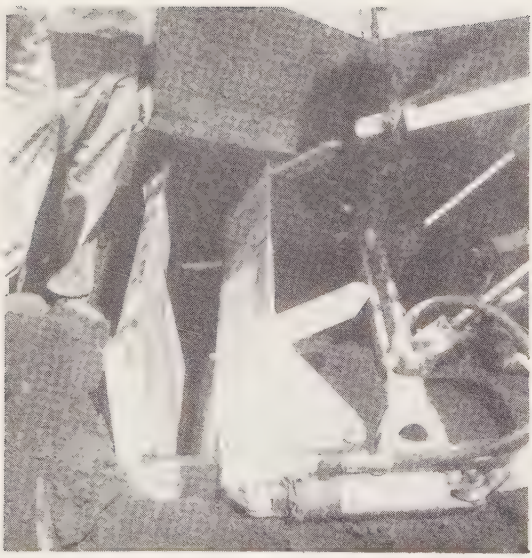


FIGURE 40. *The spile in place before split blade is removed.*

FIGURE 41. *Metal flume design for use of HSPA molded outlet in a herringbone layout at McBryde Sugar Co.*

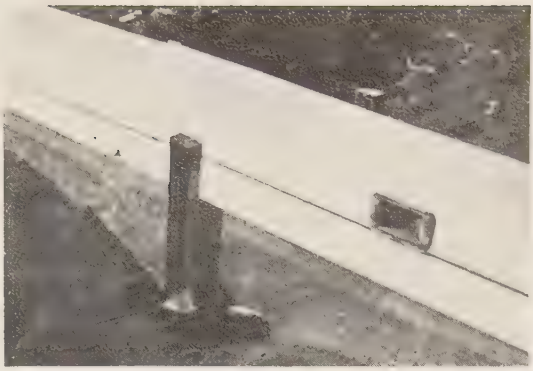


FIGURE 42. *HSPA molded outlet in removable metal section of concrete flume lines at Oahu Sugar Co.*

hspa molded outlet to be marketed

Continued use of the HSPA molded outlet at McBryde has shown good results. Leaks around the gate are being reduced by using a slightly softer material, which also allows easier installation; the sealing ridge around the gate is being extended .004 inch to give a better seal; cooling forms are being set up at the molding plant so as to bow the sides out slightly to crowd the gate slot partially shut (Figure 41).

To lessen the tendency of the outlet to come out of the flume under certain field conditions, the upstream lip is being lengthened 1/16 inch; cooling forms will be used to leave the sides bowed out for a firmer fit in the flume hole; and the supplier will modify his packing methods so as to reduce distortion in shipment.

This outlet is also being used as a side outlet in metal flume which is shaped to the cross-section of Waialua concrete flume. This metal flume is installed in concrete flume lines where the flume is removed at harvest time (Figure 42).

Hawaiian Development Company has licensed Sun Plastics Inc. to mold and sell this outlet on a world-wide basis. Sun Plastics has started a publicity and advertising program to develop a market.

MECHANIZATION

industry studies harvester methods for unirrigated areas

Headed by the Station's Principal Industrial Engineer, a special industry committee examined alternative methods of handling cane with the experimental harvester for unirrigated cane. There are two basic methods of handling:

1. The cut-convey-load harvester, which discharges the cane directly to another unit operating in conjunction with the harvester.

2. The cut-transport-transload harvester, which accumulates its own load, transports the load to a container, and then transfers its load to it.

Cut-convey-load:

Using the cut-convey-load harvester to discharge directly to regular road transport trucks is simplest and cheapest, but terrain and soil moisture conditions of the unirrigated plantations probably rule this method out. Using the cut-convey-load with cane buggies has the advantage of a simple machine combined with high harvester performance. The principal disadvantage is that the harvester-buggy combination is out of balance except at one distance from the roadway to the harvester, thus forcing harvester or buggy delays.

Cut-transport-transload:

The cut-transport-transload harvester, with a 4-ton capacity and dumping into trailers spotted infield, has the distinct advantage of simplicity of operation. The disadvantages are that the harvester will probably be more complicated and performance will be lower than for the cut-convey-load. Capital cost per harvester will be higher than for the cut-convey-load, but total capital cost for all harvesting machinery, the most meaningful figure, will probably be less. Total harvesting operating costs are estimated to be slightly less for the cut-transport-transload than for the cut-convey-load with cane buggies, providing a unit can be constructed and operated at approximately the estimates used in the analysis.

The committee recommended that the design of a cut-transport-transload harvester proceed and, if cost and performance estimates are favorable, a unit for 1962 field trials be constructed.

Cut-convey-load harvester shows promise:

Now being developed is a cut-load harvester for unirrigated cane, using a direct-load type of unit similar to the irrigated cane machine; the pickup arrangement is straight across for flat culture, as compared to the staggered arrangement for cutting in furrows.

Several different designs are introduced:

1. **Three ground cutting knives.** A large-diameter knife is located in the center of the assembly with a pickup tine on each side; outside the pickup tines are small-diameter ground cutting knives. This allows cutting at the full width of the throat of the machine. This arrangement will give good cross-line cutting as well as cutting with the line.

2. **Detrashing.** The cut-pickup-recut assembly has been designed so that a blast of air can be introduced back of and across the full width of the pickup assembly head shaft, as well as ahead of

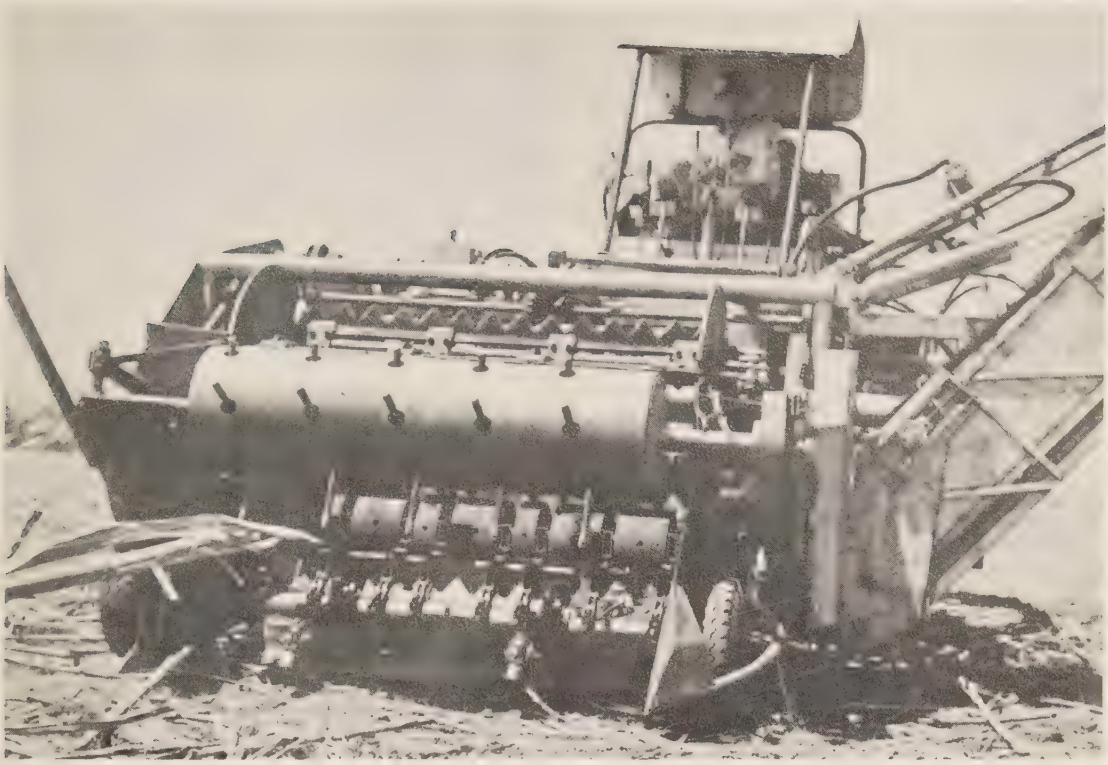


FIGURE 43. The cut-pickup-recut assembly of cut-load harvester for unirrigated cane.

the front side of the cross-load conveyor. A stream of high-velocity air will hit the cut cane as it falls away from the cross-flow cutter. The extracted trash will be blown over the back wall of the cross-load conveyor and ahead of the prime mover. Also a blast of air will be added at the discharge end of the cross-load conveyor. The detrashing at both locations will be added for the field operations in 1962.

3. **Mechanical drives.** The compactness of this cut-load assembly lends itself to effective use of mechanical drives. All components except the loading conveyor are driven by a single propeller shaft from the auxiliary engine. Mechanical drives appear to be satisfactory and have the advantage of having lower initial cost and lower horsepower losses than oil motor drives.

Initial operation has given encouraging results of good cutting across lines as well as with lines; the cutting rate has been 45 tons per hour. A limiting factor has been the capacity of the loading conveyor, now being increased.

Prototype harvester planned:

A project for developing a prototype for the cut-transport-transload harvester for unirrigated cane has been initiated by the Field Engineering Department. Drawings are complete for one basic design which will be used to solve mechanical problems and to provide estimates of weight, speeds, and cost.

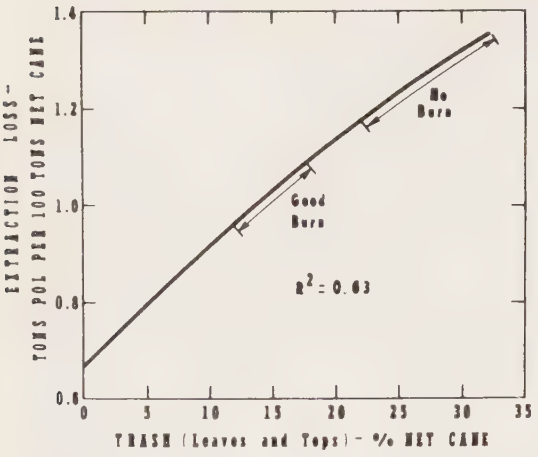


FIGURE 44. Effect of trash in unirrigated cane harvester by 9M3 harvester without detrashing. (Variety 44-3098, Laupahoehoe).

9m3 (unirrigated) harvester trash studies

The effect of leafy trash and tops on extraction and purities has been determined with cleaner-bypassed field cane harvested by the experimental unirrigated harvester without detrashing. The tests were conducted at Laupahoehoe Sugar Company with variety 44-3098. Similar tests will be conducted in 1962 with field detrashing.

Trash (leaves and tops) per cent net cane ranged from 12 with a good burn to as high as 30 with no burn (Figure 44). Extraction losses were approximately 1 ton pol per 100 tons net cane with a good burn, and approximately 1.25 tons pol per 100 tons net cane with no burn. Extraction losses with net cane were estimated at 0.67 ton pol per 100 tons net cane.

Laboratory pol ratio analyses revealed a drop of approximately 2 points in purity for trash cane with a good burn in comparison with net cane; the drop was approximately 3 1/2 points for trash cane with no burn. At Laupahoehoe, a 2-point drop in purity is estimated to cost 0.22 ton 96° sugar per 100 tons net cane.

HC&S seed cane harvester field-tested

Field testing of this machine was begun in November 1960. The design of the assemblies had been based on the design and development of the Kohala machine. The direct-mounted arrangement offered the advantages of lower first cost and more versatility, but at the expense of one place for detrashing rather than two, and one ton of storage rather than two. Field development changes required for the machine to attain production status include:

1. Improving the gathering assembly and the top ejection.
2. Increasing and streamlining the width of the gathering throat above the ground knife. The mounting of the gauge wheels was shifted from the gathering frame to the conveyor frame.
3. Adjusting the relationship between ground speed, laydown belt speed, and conveyor speed. Because of an approximate relationship which must exist among these three speeds, there is a limit to the maximum ground speed or production for a given condition. The tonnage yield of the cane being cut is also a factor, light tonnage allowing a higher ground speed. At present, the ground speed on the HC&S machine is 70 fpm, conveyor speed is 80 fpm, and laydown belt speed is 120 fpm. Topping height or stalk length is also tied in with maximum cutting speeds, since the stalks are placed into the 2-foot-wide elevating conveyor top end first. The range of topping heights has been set at 5.5 to 9 feet.
4. Moving the feed drum closer to the cross-flow cutter and lengthening laydown belts to provide more positive flow through the machine.
5. Improving the cross-flow cutter moving parts to reduce rate of wear and maintenance.
6. Designing and installing a double blower to deliver a maximum blast of air for detrashing. When operating in standard field areas, it has been possible to produce seed in the bin comparable to hand-cut seed; detrashing has been a greater problem when cutting young cane grown in high soil-nitrogen areas. The

FIGURE 45. *Direct-mounted seed cane harvester in operation at HC&S.*

FIGURE 46. *Cut-load harvester (9M2) for irrigated cane in operation at HC&S.*

optimum maximum blast has been established at 6,000 cubic feet of air per minute, with a velocity at the nozzle of 13,000 fpm, and with a power requirement at the fans of 23 hp.

7. Redesigning the mounting of the storage bin to lower the bin for loading and raise for dumping.

8. Changing the V-belt drive for driving the oil pumps to a gear box drive.

9M2 (irrigated) harvester gets trial run at HC&S

The experimental unit was first tested in 1960. The design and arrangement of the machine is based on the concept of cutting the flow of cane into manageable and easily conveyable lengths as it is lifted off the ground. In order to make maximum use of the 1960 results, the cut-pickup-recut assembly was redesigned. Changes included:

1. Eliminating the backup roll by cutting against the head shaft for the pickup chains.

2. Eliminating the two pickup tines which straddled the ground cutting knife.

3. Speeding up the components to increase the ground cutting speed from 0.75 to 1.50 mph.

4. Reducing the total weight of the cut-load assembly to 9,500 pounds. This assembly is powered by four oil motors. Use of oil power on an experimental machine gives a convenient means of determining the power requirement for each component.

Operation at HC&S has given encouraging results in the better field conditions. The following data cover the operations in Field 715 --- which had been leveled, cleared, and planed before planting; the lines were straight with uniform 5-foot spacing; the burn was excellent and the field was dry. The cane was plant cane 38-2915 with a field yield of 114.2 tons net cane per acre.

TOTAL CANE HARVESTED	445 tons, gross
TOTAL CUT-LOAD TIME	4 hrs, 12 mins.
TOTAL NUMBER OF LOADS	123
AVERAGE LOADING TIME	2 min. 3 sec. per load
AVERAGE LOADING WEIGHT	3.62 tons, gross
AVERAGE CUT-LOAD RATE	1.76 tons per minute 106 tons per hour
RANGE OF CUT-LOAD RATES	1.3 to 2.2 tons per minute 78 to 132 tons per hour
AVERAGE NET POWER FOR CUT-LOAD OPERATION ... (not including power to travel machine)	0.80 hp per ton per hour
CUT-LOAD GROUND SPEED	1.25 to 1.50 mph
AVERAGE LOAD DENSITY	12.8 lb./cu. ft.
TOTAL TRASH OR TARE	4.0%
LILIKO	2.76 tons per acre

Development work is now in progress to solve problems of: (1) gauging of the ground cutting; (2) rock protection for the cross-flow cutter assembly; and (3) desoiling.

more seed cane harvesters being built

Direct-mounted machines are being built by Honolulu shops for Oahu Sugar Company, Lihue Plantation Company, and Grove Farm Company. The major design changes from the HC&S machine are as follows:

1. All drives will be mechanical except the drives for the gathering and topping assemblies.
2. The elevating conveyor width will be 2 feet the full length of the conveyor, with a cross-flow cutting width of 25 inches.
3. The over-all width of the machine is increased 12 inches to give more clearance between the elevating conveyor and the operator on one side and the engine on the other side.
4. The engine horsepower has been increased from 99 to 118.
5. Spring shocks have been added to the elevating conveyor lift to provide flotation while cutting.
6. Design of the storage bin mounting has been changed to allow for a low or high dump.

special cane buggy tried

A self-transload track-type cane buggy has been designed and built to aid in the operation of the cut-load harvester for unirrigated cane. The body tips endwise but, instead of being dumped, the load is pushed up the slope and off the top end into a highway transport under the discharge. The operator and engine are located at the pivot end of the body, with the operator located high enough to have good visibility. The machine discharges a load of cane with minimum equipment by moving the cane up the slope to discharge into the other transport; the tail gate is opened by means of hydraulic cylinders and the load is pushed by a headboard.

Results have been satisfactory, with preliminary data showing that 25 net hp is required to move a 5-ton load of cane up a 30 degree slope at a rate of 40 fpm. This gives a transfer time of 30 seconds.

FIGURE 47. *Special cane buggy transferring load to highway transport.*

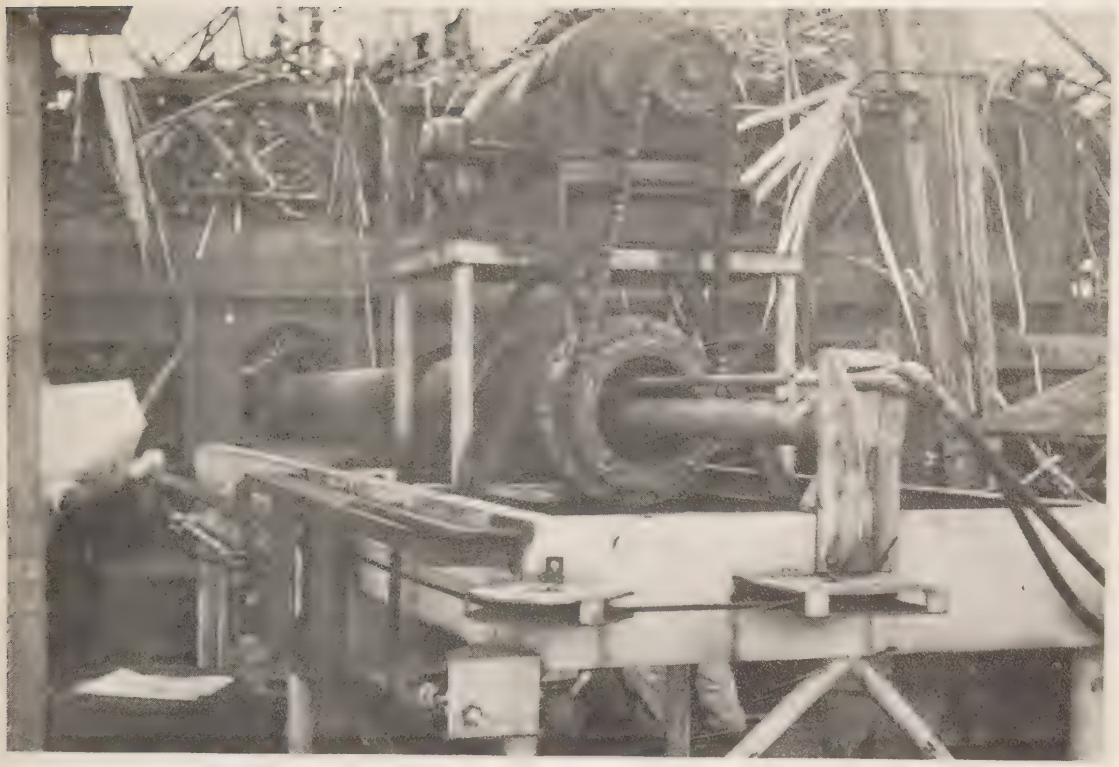


FIGURE 48. *Core sampler removing 50-pound sample from load of harvest cane at Puna Sugar Co.*

core sampler to be used at puna

Tests to check the precision of sampling truckloads of field cane with the core sampler showed a high correlation with sugar recoverable from mixed juice and led to Puna Sugar Company's plans for adopting the core-sampling device in 1962. The gasoline engine has been replaced by two electric motors for more convenient operation.

kohala seed harvester serves well

The seed cane harvester at Kohala has remained in continuous operation during the year, with satisfactory results. A heavier cross-flow cutter has been installed, and changes have been made to provide more detrashing.

grove farm to try new plan

Early in 1962 a new system will be tried by Grove Farm to eliminate the forklift and all of the bins in the plant field. A watertight truck body, designed with two widths, 8 and 10 feet, is equipped with a headboard that will push the load out the rear over a hydraulically operated tailgate. The dump mechanism is reversed to raise the rear end of the body, making possible a direct transfer from the transport into the planter bin. The plan is to have a truck without driver being filled in the seed field; in the plant field will be a similar truck, from which the planter crew will fill the planter bins. The truck driver will shuttle trucks and treat the seed at a station similar to that established at Kohala last year.

TILLAGE

roots penetrate to 10 feet in 4 months

Sugar cane inherently is a deep-rooting crop when grown under soil and climatic conditions favoring relatively unrestricted development. This is amply confirmed by recent studies with variety 50-7209 growing in a deep, well aerated soil at Makiki. The experimental setup permits direct observations of root development below ground level along a vertical soil-glass interface.

By four weeks after planting, roots were visible against the window to a depth of 1 foot; three weeks later, roots had penetrated to 40 inches. By 56 days, a few of the primary roots had progressed to a depth of 8 feet, indicating an average growth rate for the most rapidly advancing roots of approximately 1.7 inches per day. Actually, rates of 3 inches or more per day were observed for a few consecutive days; however, advance rates were usually temporarily arrested when secondary branching occurred. Extensive root proliferation to a depth of 10 feet was evident at four months.

Contrary to one prevailing concept, total length of roots per unit area of the visible soil profile did not decrease systematically with depth. In this deep, well-drained Makiki soil, there was the concentration or massing of roots in the upper layers. Moreover, numerous measurements made at various depths in the profile revealed no consistent trend in rate of root elongation (Table 22). Apparently root proliferation proceeds at an equally rapid rate to a considerable depth if conditions are nonrestrictive to growth. Observations of root growth and root activity will be continued through at least one ratoon.

TABLE 22. *Mean daily rates of cane root elongation*

Depth of Soil	16ths of inch/day	
	Primaries	Secondaries
0-3 ft.	11	12
3-6 ft.	12	9
6-9 ft.	21	10
9-12 ft.	14	None recorded

plow design modified

The project of modifying the moldboard plow has been concluded with the following results:

Moldboard:

The complex curvature of the original 32-inch bottom moldboard design had given neither satisfactory coverage nor satisfactory smoothness of plowed surface. Development and experimentation resulted in a moldboard curvature which is a section of a 47-inch diameter cylinder with a slight modification at the attachment to the share. This moldboard gave reduced draft, improved coverage, and a better smoothness of plowed surface at speeds of 1.4 to 3.2 mph.

Recommended scouring material is a high-density polyethylene supplied by Abutco Plastics Industries, Inc. This material is about one-sixth the cost of reprocessed Teflon and the rate of wear is about one-half that of reprocessed Teflon It is estimated that the cost of this material, including the labor to replace, is approximately 25 cents per acre plowed -- assuming few rocks and minimum rock damage.

Design changes:

The pivots of the standard and the shearing edges were improved to withstand frequent shearing in rocky conditions. A new shear-bar retainer was designed so as to give maximum clearance between it and the adjacent bottom throat.

The final design for the beams is a T-1 steel box section. The T-1 box section beam has double the strength of the 3-inch by 5-inch plow steel beam.

To permit the operator to change the plow suction as he operates, a hydraulic pivot was added on the Hilo Sugar plow at the connection between the cross beam and the side beams. This is of particular value with quick changes of terrain and also allows suction to be broken before the plow is lifted out of the ground.

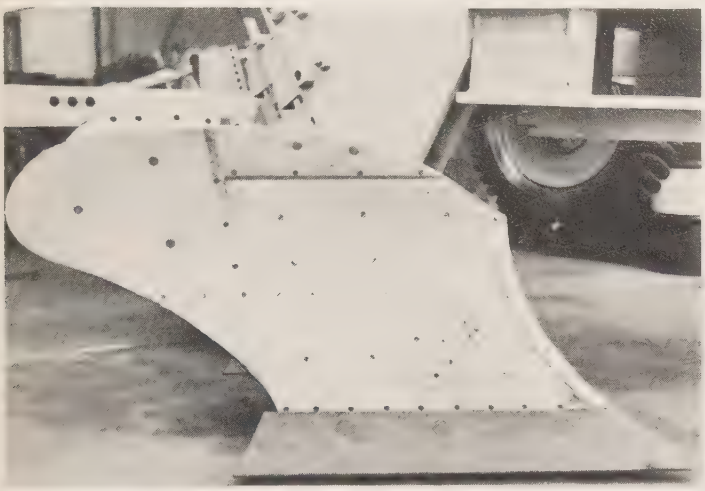


FIGURE 49. *Moldboard for 32-inch bottom cut from section of 47-inch diameter cylinder, showing final pattern and attachment of scouring material.*

FIGURE 50. *32-inch plow bottom, showing safety shear pivot and shear bar retainer.*

VARIETIES

1960-1961 crossing season

The crossing season began on November 18, 1960 and ended on January 5, 1961. The intensity of tasseling was very satisfactory and the weather was generally favorable. In spite of a slight reduction in the number of crosses accomplished, ample quantities of high-quality fuzz were produced. Germination was slightly better than usual.

The reduction in number of crosses (Table 23), when compared with the 1959-1960 season, can be attributed in part to the interference of crossing operations by the holiday schedule.

TABLE 23. *Number of crosses undertaken during 1960-1961 crossing season*

General melting pot	2,406
Leeward melting pot	424
Windward Makai melting pot	404
Windward Mauka melting pot	184
Q.R. melting pot	243
Bi-parental	667
Field	178
1960-1961 Total	4,506
1959-1960 Total	4,936

testing seedlings

The total number of 10x20 and 10x25 tests installed shows a modest increase over the previous year (Table 24). Slight declines on Kauai and Oahu have been more than offset by increases on Maui and Hawaii. The number of 40x40 and 50x50 tests installed increased on all islands except Oahu.

The number of entries in replicated tests increased substantially on Maui and Hawaii, but decreased on Oahu and Kauai.

Details of seed distribution from the regional stations to the plantations are shown in Table 25.

TABLE 24. *Preliminary tests installed by plantations*
(Fiscal year ending June 30, 1961)

	10x20 & 10x25	40x40 & 50x50
Kauai	19	34
Oahu	9	11
Maui	9	8
Hawaii	52	50
Fiscal 1961 Total	89	103
Fiscal 1960 Total	84	94

variety testing on plantations

The transition to utilization of the regional stations exclusively for the preliminary selection work has continued. No new two-year tests were planted at the regional stations in 1961. Virtually all plantations are cooperating in the 30x24 preliminary 2 – year testing stage (Table 26).

The cooperative 5x4 selection program, where plantations plant 500 to 1,000 seedlings in special and extreme environments, appears to offer considerable promise in selecting high-quality candidates for testing under these conditions. The 10x20 and later tests, involving seedlings which have passed through this program, appear to have a noticeably higher proportion of promising material than under the standard procedure. The standard procedure involves 10x20 plantings of 50 to 80 seedlings and still appears satisfactory for screening in areas similar to those represented by regional station environments.

Table 26 lists the plantings in the preliminary selection and testing program by regional stations and cooperating plantations. The marked increase in 30x24 plots reflects the adoption of this testing stage on the island of Hawaii in 1961.

TABLE 25. *Seed shipments to plantations (July 1, 1960 to June 30, 1961)*

Source	Tons for Seed Nurseries	Number of Plots For 10x20	Number of Plots For 40x40
Kailua Field Laboratory	.50	70	---
Waipio Substation	.65	1,339	9
Helemano Variety Station	----	-----	---
Hilo Makai Variety Station	2.71	850	38
Hilo Mauka Variety Station	.03	619	19
Hamakua Makai Variety Station	.84	1,073	27
Hamakua Mauka Variety Station	.48	100	---
Kohala Variety Station	1.05	-----	24
Kau Variety Station	----	187	44
Lihue Variety Station	.15	75	1
McBryde Variety Station	1.60	181	7
Totals	8.01	4,494	169
Totals 1959-1960	10.29	4,353	8

TABLE 26. *1961 preliminary testing plantings**

		Number of Seedling Plots					
	Flats**	Unnumbered 5x5	Numbered 5x4	5x10	5x15 5x20 10x10	10x20	30x24
Regional Stations							
Kailua Fd. Laboratory	1,641	2,874	385	---	-----	-----	-----
Waipio Substation	1,394	16,682	9,780	---	1,353	-----	-----
Helemano Variety Sta.	-----	4,551	3,035	---	564	-----	-----
Hilo Makai Variety Sta.	1,147	1,396	3,383	---	608	-----	-----
Hilo Mauka Var. Station	71	1,334	2,109	---	613	-----	-----
Hamakua Makai Var. Sta.	1,350	3,364	1,426	125	534	24	-----
Hamakua Mauka Var.Sta.	295	6,296	3,231	---	208	-----	-----
Kohala Variety Station	-----	991	1,644	---	447	-----	-----
Kau Variety Station	137	3,002	3,238	71	613	-----	-----
Lihue Variety Station	521	4,534	3,437	---	630	-----	-----
McBryde Variety Sta.	693	9,118	5,832	---	571	-----	-----
Plantations							
Kileauea Sugar Co.	-----	------	------	---	-----	-----	38
Lihue Plantation	-----	------	2,290	---	154	-----	114
Grove Farm	-----	------	------	---	127	-----	32
McBryde Sugar Co.	-----	------	------	---	-----	-----	96
Olokele Sugar Co.	-----	------	------	---	-----	-----	71
Kekaha Sugar Co.	-----	------	------	---	208	-----	109
Kahuku Plantation	-----	------	------	---	-----	-----	112
Waialua Agric. Co.	-----	------	------	---	-----	-----	129
Oahu Sugar Co.	-----	------	------	---	-----	-----	165
Ewa Plantation	-----	------	------	---	-----	-----	126
HC&S	-----	------	9,034	---	1,904	-----	424
Wailuku Sugar Co.	-----	------	------	---	137	-----	47
Kohala Sugar Co.	-----	------	2,573	---	195	-----	51
Honokaa Sugar Co.	-----	------	960	---	-----	-----	42
Paauhau Sugar Co.	-----	------	------	---	-----	-----	40
Hamakua Mill	-----	------	1,000	---	-----	-----	48
Laupahoehoe Sugar Co.	-----	------	538	---	-----	-----	48
Hakalau Sugar Co.	-----	------	145	---	-----	-----	-----
Pepeekeo Sugar Co.	-----	------	------	---	-----	-----	46
Onomea Sugar Co.	-----	------	------	---	-----	-----	34
Hilo Sugar Co.	-----	------	------	---	-----	-----	36
Puna Sugar Co.	-----	------	------	---	-----	-----	34
Haw'n. Agr. Co.	-----	------	641	---	-----	-----	43
Hutchinson	-----	------	1,089	---	-----	-----	38
1961 Total	7,249	54,142	55,770	196	8,866	24	1,923
1960 Total	7,500	59,855	55,527	---	8,227	461	1,078

**Breeding and spreading canes at Kailua Field Laboratory are not included in table. Plantation 10x20 and 40x40 plantings tabulated in Table 24.*

***Number of seedlings per flat: 100 to 1,000*

improved techniques for harvesting experiments

Task forces are available for harvesting experiments on all plantations. On Maui a task force maintained by HC&S has been made available to the other plantations on that island.

Pioneer Mill has adopted a Dillon remote-reading electronic load cell for weighing cane. An HSPA-designed hydraulically actuated cable clamp interposes the load cell in the closing line of the grab when a cane weight is to be taken. Pioneer has built a mobile, in-field silage chopper to avoid hauling cane samples to a central fixed chopper site. This latter practice has been standard on Oahu for several years.

On Oahu a "weighing machine" has been built to handle experimental cane. It is mounted on a rubber-tired tractor and features hydraulic operation of both the boom and the grab. One man both drives the tractor and operates the grab. Weighing is done by a remote-reading hydraulic load cell in the lift line of the grab.

FIGURE 51. *"Waipio weighing machine" for weighing cane in experimental plots. The machine features a hydraulic grab and a hydraulic load cell, seen near the boom tip, connected to a remote reading dial.*

FIGURE 52. *Remote indicator dial on the "Waipio weighing machine".*

computer speeds experiment data

The IBM 1620 Computer has been programmed to drastically reduce the man-hour requirement involved in processing data from variety experiments. A single complex "program" accepts raw data (bundle, grab or truck weights, sample weights, plot measurements, brix and pol readings, etc.) and calculates the individual plot yields (purity, fiber, TCA, P.R., P%C, TPA). The computer types the data and at the same time punches a data tape. A second complex program takes this data tape and produces a complete analysis of variance with block adjustment of seedling yields according to augmented block design analysis.

The advantages of using the computer are manifold: there is much less chance of clerical error in transcribing figures; arithmetic errors in calculations are eliminated; clerical man-hours involved are reduced from 6 to 8 hours per test to 30 to 40 minutes, including the punching of original data onto the tape. Computer time to run a test through both programs is 10 to 15 minutes, including the final type-out.

FIGURE 53. Example of "off season" cross made with photoperiod-induced 37-1933 and naturally early flowering varieties.

controlling flowering of sugar cane

The cooperative work with the USDA on flowering has been directed toward the development of effective techniques for controlling flowering, and has included some basic studies on mechanism of flowering in sugar cane. Studies in the photoperiod house with variety 37-1933 indicated that with plants on a 12.5-hour photoperiod, interruption of the middle of the dark period with 1 hour of near infrared (735 mu) light did not inhibit initiation. It was also found that floral initiation did not take place when dark interruption for 0.5 hour with red light was followed by 0.5 hour infrared light.

By inducing late-flowering varieties in the photoperiod house (with a 12.5-hour photoperiod, July 1 to September 12), 16 crosses were made with naturally early-flowering varieties during the period July 15 to October 21. The results of experiments in which plants were exposed to varying periods of night interruption and natural nights between the period August 28 and September 25 indicated that, with variety NCo 310, initiation can take place after September 12, but these plants tassel 6 to 8 weeks later than normally. These late tassels were crossed with naturally late-flowering varieties and several thousand seedlings were produced.

Maleic hydrazide, dalapon, gibberellic acid, and leaf trimming were unsuccessful when used in attempts to delay tasseling after initiation had taken place.

Twelve new chemicals were evaluated last fall. All were applied between September 1 and 13. None gave appreciable control except FB-2 (1:1 ethylene 2:2 dipyridylium dibromide). Applied at 4 pounds per acre on September 9, this

gave 78 per cent control but growth of the stalks was adversely affected. CMU and DCMU at 5 pounds per acre gave good control when sprayed between September 6 and 14, but later sprays lacked full effectiveness. This year DCMU gave better control than CMU (Table 27). It is very interesting that sprays applied after September 14 lost effectiveness in preventing initiation of flower buds but did prevent emergence of tassels (false tassels), hence casual inspection of the field gave the false impression that late sprays controlled initiation. As far as yield effects go, false tassels are just as deleterious as normal flowers.

Work is in progress on developing methods of pollen storage which would give additional scope to controlled crossing. Viability of stored pollen has been determined by seed produced in male sterile tassels. To date sorgo pollen has been stored 11 days and sugar cane pollen, 7 days.

cytogenetic studies

The cooperative studies with the USDA have emphasized:

1. Offspring of Hawaiian crosses. This material involves crosses between various noble canes and their wild relatives, both S. **spontaneum** and S. **robustum**, and appropriate backcrosses, to ascertain the manner of chromosome transmission.
2. Seedlings and clones from the 1957 New Guinea expedition. The determination of chromosome numbers is nearing completion. There remains to be made studies on meiotic behavior of this material.
3. Recent importations of "original" Fijian varieties collected by Colonial Sugar Refining Co.
4. Seedlings from the related genera Sclerostachya, Miscanthidium, Narenga, and Miscanthus.

TABLE 27. *Effect of date of spray on tassel control by CMU and DCMU*

Treatment	Spray Date	Per cent of Tagged Stalks				
		No Tassel	Tassel	False Tassel	Bunch Tops	Dead Tops
Checks						
1	---	---	94	6	-	-
2	---	6	86	6	2	-
DCMU (5 lbs./Acre)	9/6	94	--	6	-	-
	9	92	6	-	-	2
	12	100	-	-	-	-
	14	100	-	-	-	-
	16	78	-	16	6	-
	21	34	24	40	2	-
CMU (5 lbs./Acre)	9/6	76	8	14	-	2
	9	78	8	12	2	-
	12	72	20	6	-	2
	14	80	6	10	2	2
	16	16	48	34	2	-
	19	32	16	44	6	2
	21	18	38	38	-	6
	23	8	64	26	2	-
	26	4	80	14	-	2

comparing physiology and biochemistry of varieties

In the Makiki variety plots it has been found that varieties differ markedly in the following ways:

1. Early growth rate, number of stalks per stool in single-eye plantings, and in ratooning vigor.
2. The vascular bundles differ in number, arrangement and size. This may affect the ability to move water and solution through the plants.
3. Tissue analyses of moisture, sugar, N, P, and K differ when grown under comparable conditions. Hence, standards of tissue diagnosis must be established for each.
4. Quality response to nitrogen differs. Varieties may be classed according to nitrogen sensitivity.

The data in Tables 28 and 29 further emphasize varietal differences in three major constituents: moisture, N, and K. The varieties have in each case been arranged in order of moisture content. All of the nitrogen was applied within the first month. There was a steady fall in nitrogen and moisture values with age as a result of early, single application of fertilization; however, with other timing of nitrogen applications, these average values should be maintained for the first 12 months. A lower initial application would result in a lower 6-month value which would be compensated by a later application which would result in higher 12-month values.

The variety test also has plots receiving 200 pounds of N, a level definitely below the optimum at Makiki. The average effect of 200 pounds of N has been calculated from the difference between these and the 400-pound plots. Varietal range of nitrogen and moisture in both leaf and stalk is about twice as great as the effect of 200 pounds N per acre. Hence, different standards must be set for the varieties if tissue analysis is to be used as a guide to nitrogen control. The only alternative is to assume that varieties differ in their total nitrogen requirements, an assumption that has yet to be established by yield tests. There is a closer parallelism between the moisture and N in the 8-10 than in the sheath.

In the sheath the moisture and K are sometimes closely aligned. This has led to the speculation that sheath K values could be brought together for all varieties by expressing them on the wet weight basis or even on the water basis. There is considerable logic to this and in the Amfac test we found the K values to be less variable when expressed on the wet weight basis. However, Tables 28 and 29 reveal numerous exceptions to the smooth curve. When recalculated

TABLE 28. *Average leaf analyses associated with good growth of 10 varieties at Makiki. (400 lbs. N/Acre) Plant. 6, 9 & 12 mo. samples.*

VARIETY	MOISTURE	N	K
39-7028	83.8	1.77	4.10
49-104	83.4	1.56	3.23
44-2772	82.9	1.63	3.21
49-5	82.5	1.85	2.43
38-2915	82.3	1.90	2.75
39-3633	82.1	1.92	2.69
H-109	82.0	1.89	2.39
44-3098	80.9	1.93	2.71
32-8560	79.2	1.64	2.16
37-1933	78.7	1.79	2.16
MEAN	81.8	1.79	2.78
VARIETAL RANGE	5.1	0.37	1.94
EFFECT OF 200 LBS. N/ACRE	2.3	.19	

Moisture and K on 3-6 sheath; N on leaf punch.

TABLE 29. *Average 8-10 analyses associated with good growth of 10 varieties at Makiki. (400 lbs. N/Acre) Plant. 6, 9 & 12 mo. samples.*

VARIETY	MOISTURE	N	K
38-2915	87.5	.234	2.15
H-109	87.0	.239	0.97
39-7028	85.2	.237	2.03
44-3098	84.1	.281	1.99
39-3633	84.1	.206	1.29
44-2772	83.9	.165	1.97
49-5	82.2	.202	1.24
49-104	81.9	.181	1.56
32-8560	81.8	.172	1.02
37-1933	80.8	.171	1.04
MEAN	83.9	.209	1.53
VARIETAL RANGE	6.7	.110	1.18
EFFECT OF 200 LBS. N/ACRE	2.3	.062	

on a water basis, the varietal range shown in Table 30 is found. It is seen that this is about the same as given in the Amfac test by application of 400 pounds of K_2O per acre. Hence there seems to be no obvious way to calculate the varietal difference in tissue K.

TABLE 30. *Comparison of varietal K range with Amfac data.*

		Mean K
Amfac (6-8 mos.)	No K_2O	84%
	200 lbs. K_2O	102%
	400 lbs. K_2O	111%
Varieties (6-12 mos.)	H-109 (lowest)	90%
	39-7028 (highest)	115%

varietal sensitivity to nitrogen

The data in Table 31 are taken from the 12-month harvest of the ratoon crop. The varieties fall into about the same order of N sensitivity as last year. All improve with lower nitrogen and the range among varieties becomes less. Data collected to date indicate that with very low N even the poorest varieties achieve good quality.

In considering the impact of stalk structure on quality, a new study was made comparing node and internode tissue of the new variety 50-7209. This was a stool of 28 stalks, 13 months old, developed from a single-eye planting at Makiki. Results indicate that, everything else being equal, the quality is improved by a high internode:node ratio (Figure 54). The continued gain of the nodal quality with age indicates that this is the region where the final improvement is made.

TABLE 31. *Varietal sensitivity to nitrogen*

Variety	Pol % Cane	
	400 Lbs. N	200 Lbs. N
37-1933	12.0	15.1
49-104	11.7	13.0
32-8560	11.0	14.7
49-5	10.3	14.5
39-7028	9.8	11.0
39-3633	9.7	13.5
44-3098	9.6	12.0
H-109	9.2	13.5
44-2772	8.5	13.6
38-2915	7.3	11.3
Average	9.9	13.2
Range	4.7	3.8

comparing development of varieties

On August 24, 1959, six major varieties (37-1933, 44-3098, 44-2772, 49-5, 49-3533 and 50-7209) were planted as single eyes, 5 feet apart in lines 5 feet apart, in fumigated soil at Makiki. At one month of age 200 pounds N per acre was applied to some lines and others were left with zero N.

At 7.5 months of age the average number of stalks per stool ranged from 17 for 49-3533 to 30 for 44-3098 (Annual Report 1960, p. 10).

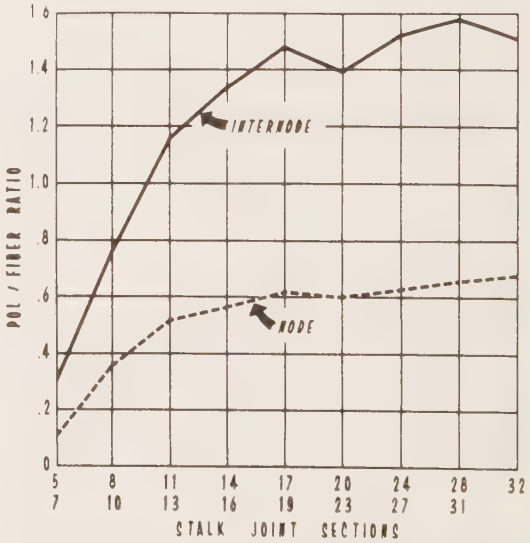


FIGURE 54. *Pol:fiber ratio of nodal and internodal tissues (variety 50-7209).*

At 16 months of age a stool of 37-1933 and one of 50-7209 were harvested. The stalks were sorted into age groups by counting the number of joints. The primaries had 58 and 61 joints, respectively, giving an average of 3.6 and 3.8 joints per month. These values are used for estimating the ages of the younger stalks. The following comparisons are of interest:

1. In both varieties the primary has lower pol and purity than the succeeding stalks.
2. In both varieties the pol and purity reach a maximum in stalks with 41 to 49 joints (11 to 13 months of age).
3. The pol and purity are highly correlated with the moisture content, e.g., the minimum moistures are found in the 11- to 13-month-old stalks and maximum in the primary (except for very young suckers in 37-1933.
4. Variety 50-7209 is consistently of higher juice purity than 37-1933 in all age groups. This results in about 10 per cent more TPA from slightly less cane. This is a varietal difference not highly correlated with moisture.
5. Only 37-1933 had produced a crop of very young suckers.

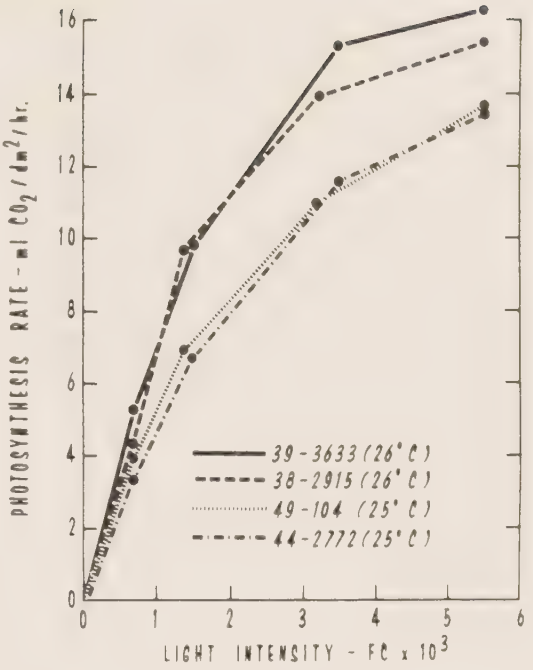


FIGURE 55. *Varietal differences in rate of photosynthesis show up best at high intensities of light (average of runs in reverse order).*

comparing efficiency of varieties

Photosynthesis:

With the installation of a recording CO_2 analyzer (LIRA) in 1960, a study was made of the comparative rates of photosynthesis of ten varieties growing at Makiki. Since measurements in the field were too difficult to control, the study was directed to detached leaves which were subjected to exactly repeatable laboratory conditions.

Within a variety the photosynthetic rate of leaves spread over a considerable range. After studying large numbers of cases it seems that our current commercial varieties may differ in rate by as much as 20 per cent. It is shown in Figure 55 that 39-3633 and 38-2915 maintain higher rates than 49-104 and 44-2772 over the entire range of light intensity. This means that with equal leaf area and light intensity the former varieties make more sugar.

In a similar study 39-3633 maintained higher rates than 49-104 and 37-1933. In this case the light intensity was carried to 8,000 fc. Of the three varieties, only 37-1933 did not reach saturation light intensity.

Many factors enter into the over-all capacity to make sugar by photosynthesis. It has been shown that the normal CO_2 of the air (310 to 320 ppm) is sufficient for maximum rates and, therefore, is not a limiting factor.

The ability of varieties to maintain high rates of photosynthesis throughout the day could be of paramount importance. Variety 49-104 starts high but by the time it has had six determinations made and the light intensity increases again the rate has fallen to about half the original rate; and 38-2915 shows a progressive drop in rate after the first few hours at 5,500 fc.

TABLE 32. *Leaf dry matter required to produce mill cane and sugar with 200 lbs. N/acre in 12 months*

Variety	Per cent of Mill Cane		Sugar/ Leaf
	Leaf	Total Sugar	
37-1933	33.6	52.1	1.57
38-2915	51.1	47.4	0.88

Plant waste:

There has been much work done on the amount of total photosynthate which goes into useful stored sugar. Usually this is limited to expressions of sugar: fiber ratios in millable cane. However, it has been found that in general about one-third of the photosynthate went into each of the major above-ground parts: cane fiber, sugar, and leaf.

In a single study of this, made on ten varieties at Makiki, large differences were found in the amount of waste material. The two extremes, 37-1933 and 38-2915, are compared in Table 32. In order to avoid penalizing 38-2915 for its poorer sucrose:reducing sugar ratio at 12 months, calculations were made on total sugar (S+RS). For each pound of dry leaf matter of variety 37-1933, 1.57 pounds of total sugar have been stored at 12 months; but in 38-2915 only 0.88 pound, or 56 per cent, as much sugar has been stored. This is a quantitative expression of the term "leafy variety".

WEED CONTROL

screening new herbicides

A total of 125 chemicals of potential herbicide value was received for preliminary laboratory evaluation during the year. With the screening methods developed by the Station, it has been possible to characterize these chemicals as to their action on plants and as to their quantitative comparison with other chemicals of the same general type. Herbicides considered worthy of continued field testing in Hawaiian cane fields are:

CONTACTS
(effect only on treated portion of plant)

Diquat (formerly FB-2) and *Paraquat*, at 1 to 2 pounds per acre, are used for cane desiccation at harvest to reduce green trash. *Paraquat* has higher activity on grasses.

LEAF ABSORBED SYSTEMICS
(translocate from leaves throughout plant system)

3-amino-1,2,4-triazole (amitrol) is for use on rhizomatous and non-rhizomatous grasses, and in 2,4-D restricted areas for broadleaves. FDA clearance is under consideration.

ROOT ABSORBED SYSTEMICS
(pre-emergence soil-applied chemicals, translocate upward from the root system)

Prometone is good on heavy soils as a soil application for pre- and post-emergence of most weeds in sugar cane.

Prometryne, *Atrametryne*, and *duPont 326* are good on heavy soils under low moisture conditions as a soil application for pre- and post-emergence of most weeds in sugar cane; *duPont 326* is not recommended for heavier soil areas.

Monsanto CP-17029 and *CP-31675*, *Hercules AC-7175* and *Casaron* are used as a soil application for pre-emergence of most weeds in sugar cane.

emulsifier developed

The Station has developed an oil-soluble emulsifier for pentachlorophenol in locally available aromatic oils. The concentrate carries one pound pentachlorophenol per gallon and emulsifies on addition of five to eight times its volume of water. The emulsifier, which is a 95 per cent active liquid amine salt of an alkyl aryl sulfonate, was given the name Osamul-95 and is made for the industry by Pilot Chemical Company.

measuring phytotoxicity

Many variables, such as soil adsorption and moisture levels, affect the field behavior of soil-applied chemicals which must enter the soil solution and be absorbed by photosynthesizing plants before they are active. Since it is impossible to get meaningful results by growing plants in a single soil either for laboratory screening or field evaluation, it is necessary: (1) to know the quantitative intrinsic phytotoxicity levels exhibited by various chemicals or various plant and weed species without the soil/climate variables; (2) to know what the influences of soil type and ecological differences will be; and (3), to measure the effects from use of the chemicals on sugar cane.

Intrinsic phytotoxicity is measured by adding chemicals at various concentrations to the nutrient solution surrounding the roots of photosynthesizing plants (Figure 56). Measurements are made of the per cent inhibition of the second true photosynthetic leaf compared to a control. Translocation of the chemicals could only be upward from

FIGURE 56. *Laboratory evaluation of herbicide chemicals applied to plant roots -- 7 days after application.*

the roots through the xylem tissue or, in the case of a strong contact, the root tissue might be destroyed and the plant would then die of starvation.

Compared to the newer chemicals, 2,4-D, STCA, and sodium chlorate have performed poorly, although STCA has relatively more activity on grasses. Species variabilities have yet to be explored. Table 33 summarizes test data obtained on the chemicals in general use in Hawaii, including amitrol which is under consideration.

TABLE 33. *Phytoxicity ratings* on herbicides frequently used in Hawaii.*

	CONTACT (SEED)		SYSTEMIC (SEEDLING)		PRE-EMERGENCE (ROOT)
CHEMICAL	BL	G	BL	G	BL
AMITROL	E	F	A	C	F
SODIUM DALAPON	F	F	F	D	-
DCMU	F	F	E	D	A
CMU	F	F	D	F	A
PENTACHLOROPHENOL	B	A	B	C	D
SILVEX (ACID)	C	C	B	C	-
SIMAZINE	F	F	F	D	A
STCA	F	F	E	E	F
2,4-D (ACID)	C	C	A	C	C
2,4,5-T (ACID)	C	C	A	D	-
ATRAZINE	F	F	E	F	A
SODIUM CHLORATE	F	F	F	F	F

BL = broad leaf, generally radish or cucumber; G = grass, generally sudan
**Rating: A = very strong, B = strong, C = moderate, D = fair, E = some, F = none or stimulation.*
Herbicides were tested at equivalent concentrations.

field-testing herbicides

Cooperative field testing has included 154 herbicide observation tests at Waipio and on plantations. The triazine compounds make up the bulk of the chemicals tested, with substituted urea compounds next in number. Additional clearance for Simazine 80W has been obtained, allowing one application over cane at the rate of 2.5 to 5 pounds per acre no later than 2 1/2 months after planting or ratooning. Atrazine has also been cleared for one application as pre-emergence or post-emergence at rates of 2.5 to 5 pounds per acre each, or as directed interline spray for a total not to exceed 12.5 pounds of Atrazine 80W. Other compounds showing promise are Prometone for pre-emergence use and D-326 for pre-emergence or early post-emergence application.

OSA (pentachlorophenol) has been cleared for use in sugar cane at rates of 50 pounds per acre for pre-emergence, and 10.5 pounds per acre for post-emergence applied at least 18 months before harvest.

disappearance of cmu in cane

The rate of disappearance of CMU in sugar cane has been measured by applying the chemical over 20-inch cane at rates of 2, 4, 8, 12, and 16 pounds per acre with three replicates each of 49-5 and 44-3098. Periodic samples of cane and soil were analyzed for residual CMU. The results are shown in Figure 57. Variety 44-3098 showed far more symptoms of visual injury than did 49-5 but, since there was no significant difference in the uptake of CMU by the two varieties on a dry-weight basis, the two varieties were combined in the figure. Since CMU is known to be stored in the leaf margins, it is significant that the disappearance of CMU occurs at a rate about equal to the complete turnover of the cane leaf system. Disappearance, then, occurs most likely by leaf abscission. In the 2-year crop, the cane will be free of residual CMU for at least 16 months after the initial pre-emergence application. Soil residual disappearance occurred at a nearly uniform rate to zero in about 1 year.

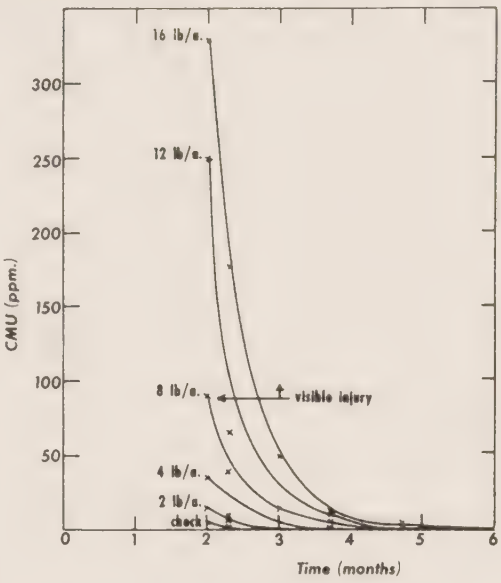


FIGURE 57. CMU *disappearance in sugar cane. Hakalau test 49-25, field 118; one application over 20-inch cane; varieties 44-3098 and 49-5; soil adsorption 67%.*

applying herbicides in irrigation water

Application of herbicides in irrigation water is not new. The principle has been tested in previous years, especially with 2,4-D. Because of variability in water distribution with even the best irrigation layout, there has been too much damage from 2,4-D from heavier applications. Tolerance of sugar cane to most other herbicides is too low to chance over-application in large field areas.

Tests with OSA (pentachlorophenol) and WSA (sodium pentachlorophenate) show high tolerance of sugar cane to these two herbicides. Levels as high as 2,000 pounds per acre have not reduced germination, although this level did affect early cane growth; however, recovery was complete by eight months. Where 1,000 pounds per acre and less were applied, the sugar cane growth equalled the check plot from the beginning. With such high tolerance in the crop, it is possible to apply the herbicide in irrigation water.

As for liquid fertilizers, the chemical is dispersed from a tank with flow meter, placed near the main ditch leading into a field. WSA in aqueous mix (possibly as fluid activator stock), OSA as ARCON (ARCADE Concentrate), or water-miscible Osamine can be mixed satisfactorily with the irrigation water in normal flow.

During 1961, over 2,500 acres have been treated with ARCON at Pioneer. Large-scale tests have also been conducted with ARCON and Pentacide in irrigation water on several plantations. This has particular value of supplementing other pre-emergence treatments to prevent weed growth in the cane line; in large part, it eliminates the need for contact sprays adjacent to cane plants.

Some improvement in cane growth has been noted in plots and areas treated with OSA in comparison with untreated checks. This indicates the possibility of deleterious microorganisms in the soil having been controlled by the herbicide.

pentachlorophenol cleared for use

Analysis of sugar cane stalks grown for 3 months in a soil where pentachlorophenol had been applied as a pre (cane) emergence treatment of from 0 to 3,000 pounds per acre showed that no PCP residue resulted up to 2,000 pounds per acre, with a small amount (less than 0.5 ppm) in the 3,000 pounds per acre plot. These data were submitted to the USDA, resulting in a zero residue clearance for 50 pounds per acre as a pre (cane) emergence treatment.

adsorption of herbicides by soils

Soil adsorption of all herbicides removes considerable quantities of chemical from available use. Hawaiian sugar cane soils, except subsoils, adsorb larger quantities than do most Mainland soils. Determination of adsorption of CMU and DCMU on 101 sugar cane soils resulted in the variable distribution shown in Figure 58. So far, the only correlation that can be made with soil properties is a rough division by soil type in which the darker group soils and the Molokai family of the red low humic latosols are highly fixing, the humic and hydrol humic latosols are intermediate-high, the humic ferruginous latosols are intermediate-low, and the Kahana and Hailimaile silty clays of the low humic latosols are low. It appears that the quantitative adsorptive pattern for each soil will depend on the chemical structure of the herbicide; particle size distribution and, to a lesser degree, the organic fraction are the principal soil factors influencing adsorption of non-ionic herbicides.

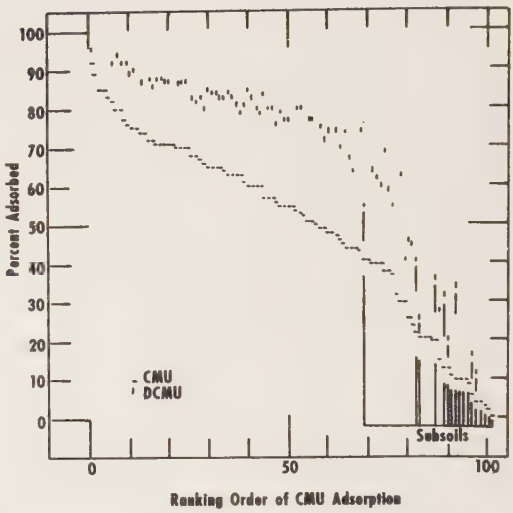


FIGURE 58. *Adsorption of CMU and DCMU in Hawaiian sugar cane soils.*

herbicide-tolerant weeds are studied

Study of several strains of Bermuda grass (*Cynodon dactylon* L. pers) has continued in an attempt to find a herbicide that will either control the grass for long periods or achieve complete kill. Herbicides tested to date include dalapon, TCA, Amitrol, and a combination of dalapon and Amitrol. Amitrol appears to provide the longest period of control but complete kill is questionable (Figure 59). The dalapon-Amitrol

FIGURE 59. *Manienie control at Kilauea. Ditchbank infested with Bermuda grass that is highly tolerant of TCA or dalapon. Compare plot in foreground treated twice with Amitrol with check plot in background.*

combination gives the most rapid action but length of control is less than with Amitrol alone. Dalapon alone remains effective as a control agent on most strains and is the only one that can be recommended since Amitrol is not cleared for use in fields. TCA in combination with dalapon is also a satisfactory means of control.

After repeated sprayings of dalapon, several types of crab grass (*Digiteria* spp.) have recently shown poor control. Work is presently being done to determine whether this is a herbicide-tolerant strain, and if it is, what herbicide will control it most effectively.

controlling panicum repens

A test has been established at Mokuleia in cooperation with the Department of Agriculture to find a means of controlling or eradicating *Panicum repens*. Herbicides tested are: TCA, dalapon, dalapon-TCA, dalapon-amino triazole, amino triazole-CMU, CMU, dalapon-CMU, Ammate, M-1515, and sodium chlorate. High levels have been applied without effecting eradication; however, control is possible with repeat applications. Most promising were amino triazole-CMU, CMU, and high levels of sodium chlorate.

fiberglass tanks tested

Pressure tanks fabricated from fiberglass embedded in polyester resin have been assembled into both single- and double-tank knapsacks (Figures 60 and 61). Tests indicate the following:

1. 750 pounds per square inch was necessary to burst a tank under hydrostatic pressure.
2. There is low tolerance of impact. Both empty and full tanks burst when dropped from a height of 8 feet.
3. Tests with many chemicals, both acid and alkaline, have shown no deterioration of the tanks in a 2-year period. Aqua ammonia should not be used in fiberglass units.
4. Apparently satisfactory strength is incorporated to insure safety of operation under normal conditions. Tanks must be protected against damage from dropping or from excessive jostling in transport.

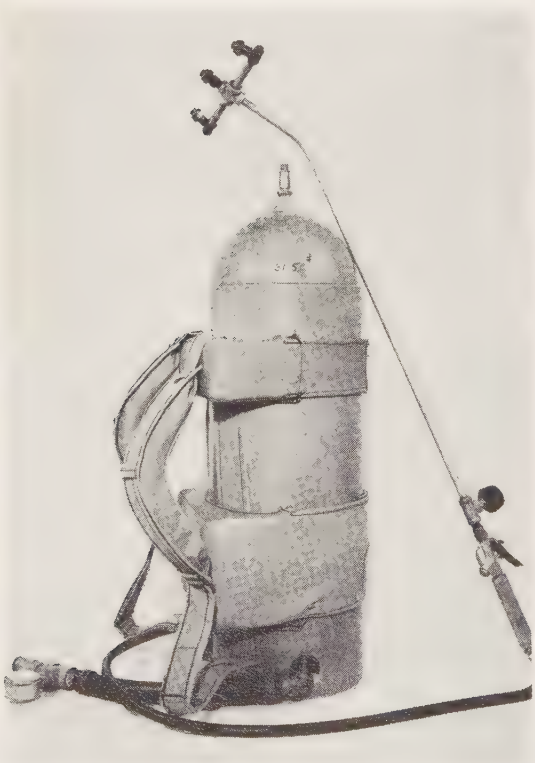


FIGURE 60. *Single-tank pressure knapsack of fiberglass.*

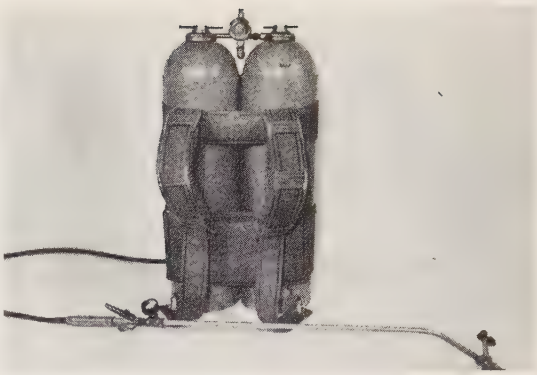


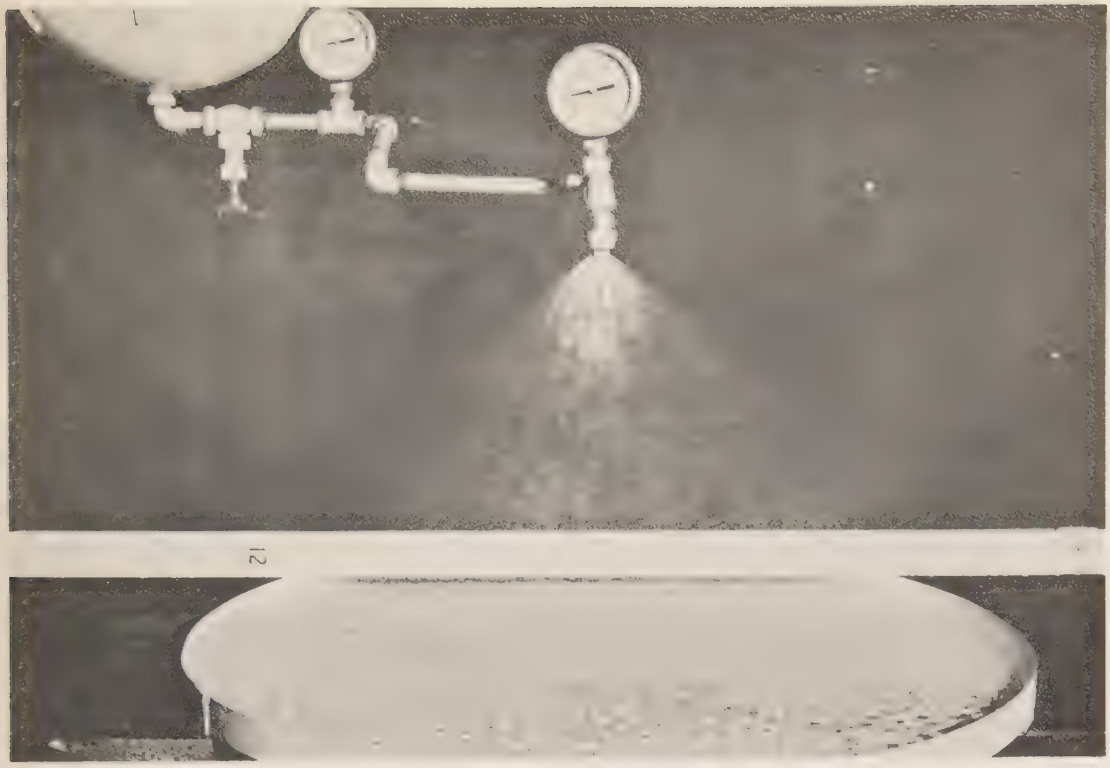
FIGURE 61. *Double-tank pressure knapsack of fiberglass.*

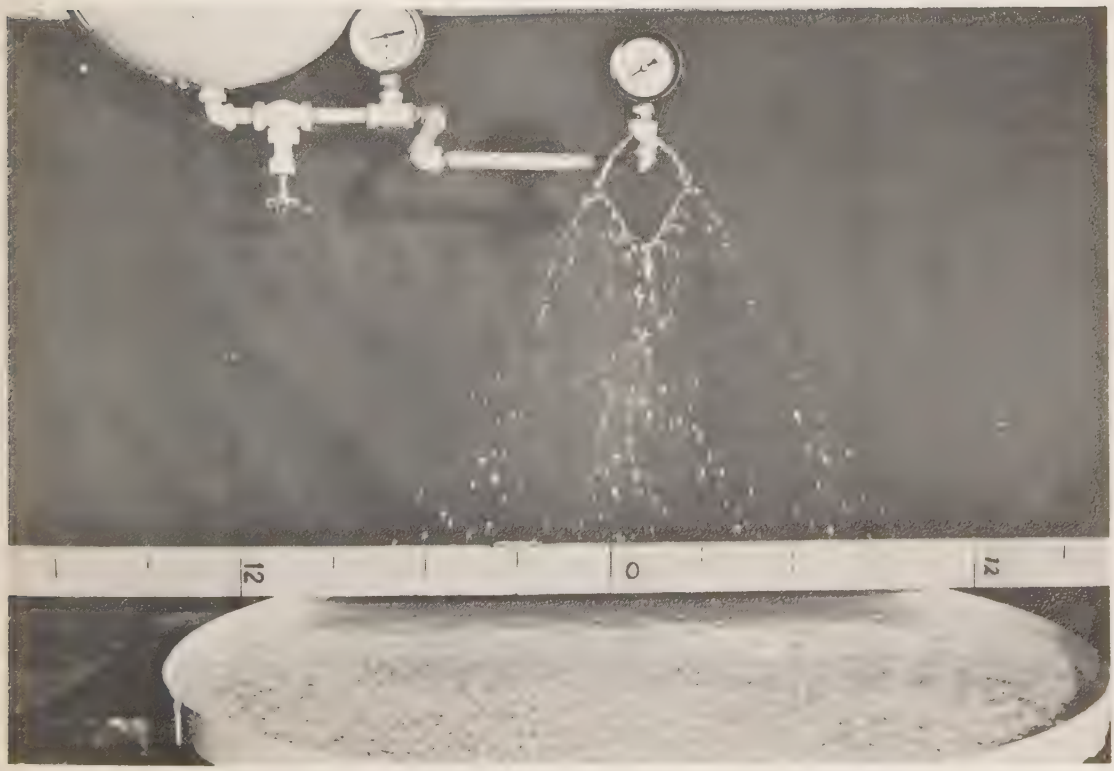
controlling spray drift

When the regular fan- or cone-type nozzle is operated at relatively high pressure, and even as low as 30 pounds per square inch, a small percentage of the liquid being applied is broken into droplets so fine that they run out into infinity to become gaseous rather than liquid (Figure 62). Droplets of aqueous liquids or oils, less than 10 microns in diameter, are so light in weight that they may be carried along on wind currents for great distances. Where herbicides are involved, this may lead to damage to plants sensitive to such herbicides.

Studies in a wind tunnel at the Waipio Substation with low-pressure sprays have shown that some nozzles operated at 4 pounds per square inch or less, regulated with a small orifice before the main nozzle, provide a pattern of droplets in excess of 50 microns in diameter, with a consequent maximum drift of about 50 feet when dispersed 15 to 20 inches above ground in air velocity of 14 to 15 miles per hour (Figure 63). A list of recommended nozzles for spray drift control is now available.

Above, FIGURE 62. *Fine spray and mist from Teejet 11008 nozzle at 30 psi.*
Below, FIGURE 63. *Coarse, narrow spray pattern from low-pressure spray nozzle.*


12


12
0
12

air flow may be useful in weed control

Tests have been conducted in laboratory, wind tunnel, and field with units incorporating air flow to distribute concentrated liquid herbicides in place of diluted sprays. These tests indicate that the principle of using air flow has definite possibilities, and that the units presently on the market in Hawaii can be used for this purpose, although the units can be improved for use in sugar cane.

These units consist of a small engine and fan mounted on a knapsack to be man-carried. A tank containing approximately 2.25 gallons is mounted at the top to provide gravity flow to the nozzle. The air stream from the fan carries the concentrated spray away from the nozzle, breaking it up into droplets of fairly uniform size. Droplet size is dependent on speed of the motor and fan and the consequent velocity of air flow; rate of liquid flow is regulated by size of the orifice preceding the nozzle or by valve opening.

A unit such as this can also be used as a duster. It is not acceptable to apply present herbicides as dusts in sugar cane fields, but there remains a distinct possibility of treating ditches, trails, and field edges by dusting. Tests show definite possibilities for the application of concentrated systemic herbicides as sprays into dense areas of woody plant growth where movement of men and the equipment for spraying is limited.

applying herbicides in soil

The value of incorporating 2,4-D, the substituted ureas, triazines, or Eptam in the upper 1-inch of soil has been studied both by subsurface spraying and by rototilling immediately after spraying the surface of the soil. Tests at the Waipio Substation have favored the rototilling principle over either subsurface spraying or application at the surface only. The subsurface sprayer is shown in Figure 64.

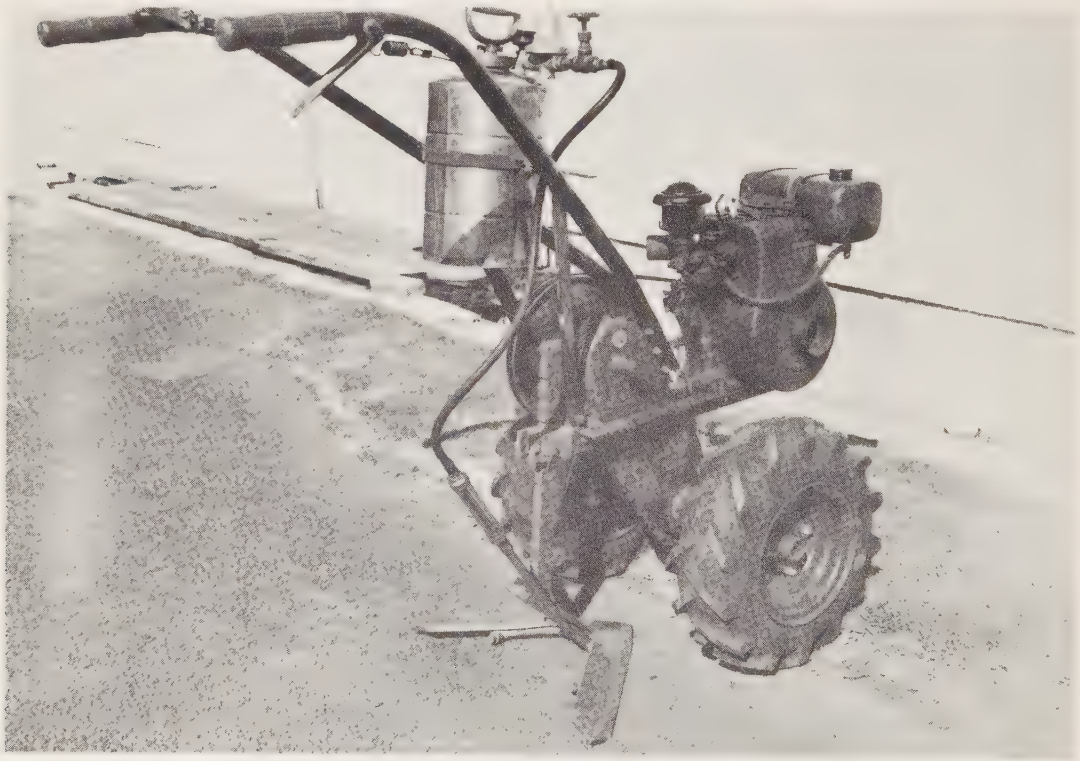
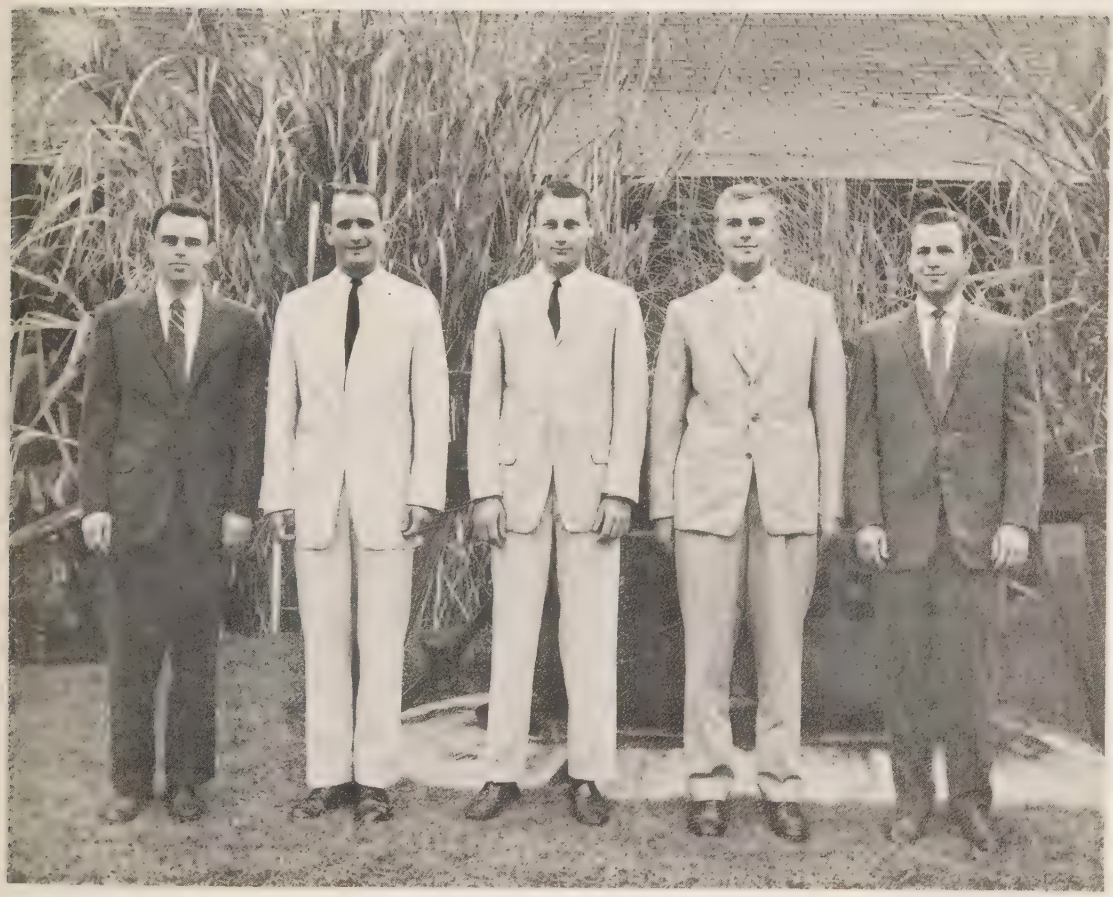


FIGURE 64. *Subsurface sprayer for incorporating herbicide into soil.*

PERSONNEL TRAINING



PLANTATION AND AGENCY
ENROLLEES IN AGRICULTURE

Norman Rozeff, *C. Brewer*
Charles B. Henderson, *C. Brewer*
Michael C. Baldwin, *HC&S*
Coenraad F. Stork, *C. Brewer*
Antonio M. Tremols, *C. Brewer*

ASSISTANTS-IN-TRAINING

Robert F. Willmot, *Agriculture*
Edwin K. Stilwell, *Agriculture*
George W. Freeland, *Agriculture and Sugar Technology*
Allen S. Hall, *Agriculture and Sugar Technology*
INSET:
Vernon K. Yamamoto, *Sugar Technology*

EXPERIMENT STATION STAFF

SEPTEMBER 30, 1961

ADMINISTRATION

L. D. Baver.....*Director*

BUSINESS OFFICE..... F. D. Kennedy.....*Business Manager*
F. W. Littlejohn.....*Assistant Business Manager*

BUILDINGS AND GROUNDS

William Sa Ning.....*Superintendent* Y. Okura.....*Foreman*

INSTRUMENT SHOP

Gordon Furmidge.....*Instrument Technologist* G. E. Lambert.....*Instrument Technical Assistant*
G. E. Sloane.....*Technical Consultant*

LIBRARY

Charlotta M. Hoskins.....*Librarian* Jean Dabagh.....*Assistant Librarian*
Harriet Iwai.....*Senior Library Assistant*

PUBLICATIONS AND GRAPHIC ARTS ..... Edith L. Haselwood.....*Publications Manager*
Jean Dodge.....*Publications Assistant*
J. T. Yamamoto.....*Graphic Artist and Photographer*
A. N. Prather.....*Consultant*

ISLAND REPRESENTATIVES

OAHU	*HAWAII*	*KAUAI*	
F. C. Denison	O. H. Lyman	D. S. Judd	*Senior Island Representative*
.....	K. Kunimitsu	.....	*Assistant Island Representative*
M. McPhail	.....	Y. Inouye	*Assistant to Island Representative*
.....	A. Sato	.....	*Substation Overseer*
J. Bumanglag	H. Oba	.....	*Senior Substation Assistant*
J. K. Mitchell			
L. Nakatsuka			
.....	R. K. Conant	.....	*Task Force Supervisor*

AGRONOMY

George Stanford.....*Principal Agronomist*

A. S. Ayres.....*Senior Agronomist*
R. B. Campbell.....*Senior Agronomist*
A. C. Trouse, Jr. .....*Senior Agronomist*
Richard Boyen.....*Executive Assistant*
Jen-Hu Chang.....*Associate Agronomist*
M. Doi .....*Associate Agronomist*
H. Hagihara .....*Associate Agronomist*
F. E. Robinson.....*Associate Agronomist*
T. S. Jones .....*Assistant Agronomist*
H. M. Lee .....*Assistant Agronomist*
Mon Yet Lum .....*Assistant Agronomist*
Y. Yamasaki.....*Assistant Agronomist*
W. H. Narahara.....*Administrative Agronomy Assistant*
H. Asato.....*Senior Agronomy Assistant*
T. Hayashi .....*Senior Laboratory Assistant*
K. Kawamura.....*Senior Laboratory Assistant*
Henry Mau .....*Senior Laboratory Assistant*

CHEMISTRY

H. W. Hilton.....*Principal Chemist*

Q. H. Yuen .....*Senior Chemist* R. E. Temple.....*Assistant Chemist*
George Uyehara.....*Assistant Chemist*

ENTOMOLOGY

F. A. Bianchi ..... *Principal Entomologist*

J. W. Beardsley, Jr. ..... *Associate Entomologist*

W. R. Smythe ..... *Assistant Entomologist*

J. S. Rosa ..... *Technical Assistant*

EXPERIMENTAL STATISTICS

J. G. Darroch ..... *Principal Statistician*

R. K. Tanaka ..... *Assistant Statistician*

Harriet C. Suzuki ..... *Statistics Technical Assistant*

FIELD ENGINEERING

R. A. Duncan ..... *Chief Engineer*

E. R. Bolles ..... *Senior Design Engineer*

W. P. Burton ..... *Project Engineer*

W. E. Hart ..... *Research Engineer*

C. B. Holtwick ..... *Project Engineer*

E. M. Norum ..... *Project Engineer*

T. Adachi ..... *Design Engineer*

L. H. Anderson ..... *Test Engineer*

S. Kawamura ..... *Design Engineer*

S. Matsuoka ..... *Design Engineer*

T. R. Uyechi ..... *Assistant Project Engineer*

J. M. Feiteira, Jr. ..... *Assistant Design Engineer*

J. H. S. Kim, Jr. ..... *Assistant Design Engineer*

Y. Isa ..... *Shop Foreman*

GENETICS

J. N. Warner ..... *Principal Geneticist*

Sam Price ..... *Associate Geneticist (Coop. USDA)*

R. Urata ..... *Associate Geneticist*

A. Doi ..... *Assistant Geneticist*

B. K. Nishimoto ..... *Assistant Geneticist*

H. Terayama ..... *Assistant Geneticist*

R. Chi ..... *Senior Genetics Assistant*

N. Kimura ..... *Senior Genetics Assistant*

K. Nishimoto ..... *Senior Genetics Assistant*

M. Tanaka ..... *Field Laboratory Superintendent*

INDUSTRIAL ENGINEERING

Warren Gibson ..... *Principal Industrial Engineer*

D. J. Dougherty ..... *Senior Industrial Engineer*

R. B. Arakaki ..... *Assistant Industrial Engineer*

MOLOKAI QUARANTINE STATION

George Otsuka ..... *Field Laboratory Superintendent*

PATHOLOGY

J. P. Martin ..... *Principal Pathologist*

C. A. Wismer ..... *Senior Pathologist*

H. Koike ..... *Associate Pathologist*

A. S. Miura ..... *Senior Laboratory Assistant*

PHYSIOLOGY AND BIOCHEMISTRY

G. O. Burr ..... *Principal Physiologist and Biochemist*
(Retiring November 1, 1961)

L. G. Nickell ... *Principal Physiologist and Biochemist*

H. W. Brodie ..... *Senior Physiologist*

Constance E. Hartt ..... *Senior Physiologist*

H. P. Kortschak ..... *Senior Biochemist*

David Takahashi ..... *Associate Biochemist*

T. Tanimoto ..... *Associate Biochemist*

R. B. Coleman ... *Assistant Physiologist (Coop. USDA)*

Ada Forbes ..... *Assistant Physiologist*

R. S. Yoshida ..... *Technical Assistant*

SUGAR TECHNOLOGY

J. H. Payne ..... *Principal Technologist*

G. E. Sloane ..... *Senior Technologist*

Chen-Chuan Tu ..... *Senior Technologist*

R. K. Hamilton ..... *Associate Technologist*

Toshio Moritsugu ..... *Associate Technologist*

L. J. Rhodes ..... *Associate Technologist*

F. J. Dupin ..... *Scale Inspector*

K. M. Onna ..... *Assistant Technologist*

W. T. Shiramizu ..... *Senior Laboratory Assistant*

TRAINING DEPARTMENT

N. S. Hanson ..... *Principal Coordinator*

WEED CONTROL RESEARCH

N. S. Hanson ..... *Principal Scientist in Charge*

R. D. Wiemer ..... *Assistant Scientist*

STATION PERSONNEL CHANGES

JOINED THE STAFF		
M. McPhail	*Assistant to Island Representative*	Island Representative - Oahu
L. G. Nickell	*Principal Physiologist and Biochemist*	Physiology and Biochemistry
W. T. Shiramizu	*Senior Laboratory Assistant*	Sugar Technology
LEFT THE STAFF		
D. W. Davis	*Assistant Geneticist*	Genetics
F. Johnson	*Assistant to Island Representative*	Island Representative - Oahu
M. Maeda	*Foreman*	Makiki Buildings and Grounds
G. S. Palmerton	*Assistant Design Engineer*	Field Engineering
C. Potter	*Nursery Superintendent*	Botany
K. A. Sund	*Senior Chemist*	Chemistry
RETIRED		
A. J. Mangelsdorf	*Principal Geneticist*	Genetics
DECEASED		
H. S. Iwata	*Technical Assistant*	Sugar Technology